RESERVE BANK
OF AUSTRALIA

Liquidity and Funding Markets

Liquidity and Funding Markets

Proceedings of a Conference

Held in Sydney
on 19–20 August 2013

Editors:
Alexandra Heath
Matthew Lilley
Mark Manning

Website: www.rba.gov.au

Cover Design
Reserve Bank of Australia

Printed in Australia by Reserve Bank of Australia
65 Martin Place
Sydney NSW 2000
Tel: 61 2 9551 8111
Fax: 61 2 9551 8000

ISBN 978-0-9874673-2-4 (Print)
ISBN 978-0-9874673-3-1 (Online)
Sydney, December 2013

Table of Contents

Introduction

Alexandra Heath and Mark Manning

In today's diverse and globally interconnected financial system, a wide range of intermediaries are involved in the process of channelling funds from savings to investments and providing risk sharing, insurance and transactions services to households and firms. For smooth flow of funds it is critical that this complex system operates effectively. This in turn relies on stable and efficient markets in which intermediaries can fund their activities and access liquidity.

These markets clearly broke down in the global financial crisis that began in 2007. Indeed, the failure of funding and interbank markets was a major contributor to the severity of the crisis. Uncertainty as to individual institutions' exposures to problem securitised assets, or to other institutions with such exposures, led to a loss of trust and confidence in unsecured markets. Institutions began to hoard liquidity or engage in fire sales of less-liquid assets. At some points during the financial crisis, large segments of the financial system ceased to function almost overnight, leaving certain non-financial markets in many economies, such as that for real estate, without access to finance. Central banks had to step in with decisive monetary policy action and special programs to support the flow of liquidity. And governments were forced to offer guarantees of wholesale funding as well as retail deposits to underpin risk-sharing activity between intermediaries.

Against this backdrop, the theme of the 25th annual RBA Conference was liquidity and funding markets. The objectives were threefold:

- To examine how the role of these markets has evolved over time and how academics and policymakers have changed the way they think about these markets in light of the experience during the crisis.
- To understand better the dynamics at play during the financial crisis – such as the role of different intermediary types and the role of collateral markets – and to identify the particular points of vulnerability highlighted by the crisis.
- To reflect on the policy response to the crisis, examining how the exit from unconventional monetary policies and implementation of the breadth of regulatory change that has followed could transform the way that liquidity flows through the financial system and how funding markets function.

The first session focused on the evolution of funding markets and liquidity. The two papers presented in this session look at the evolving roles of different markets and intermediaries. The paper by Manmohan Singh maps out the shadow banking system, focusing on the 'financial lubrication' provided by markets for collateral. Singh highlights the importance of these markets for channelling liquidity within and between the bank and non-bank sectors, and observes that the effectiveness of these markets may have declined since the onset of the financial crisis. In particular, Singh points to both regulatory and behavioural factors that have driven a fall in 'collateral velocity' – the number of times, on average, that a single piece of collateral is re-used in a given period. This has reduced the 'effective' supply of collateral precisely when demand for collateral is increasing. Much of the discussion centred around the policy implications of the developments described in Singh's paper. Key questions emerged such as: What is the optimal level of collateral velocity? How does collateral velocity translate to real economic outcomes?

Collateral is also a central theme in the second paper, by Alexandra Heath, Gerard Kelly and Mark Manning. A key element of the post-crisis reform agenda has been to strengthen counterparty risk management and reduce interconnectedness in over-the-counter (OTC) derivative markets by requiring that exposures be collateralised and that standardised trades be cleared through central counterparties (CCPs). Given assumptions about the structure of OTC derivative markets and the characteristics of OTC products, the paper starts by examining exposures and collateral demands under alternative clearing arrangements. The paper goes on to consider the implications for financial stability of alternative arrangements revealing a trade-off between the benefits of collateralisation in managing counterparty credit risk and the costs in terms of increased liquidity risk as the balance sheet becomes more encumbered. Finally, the paper observes that the costs associated with higher liquidity risk could fall disproportionately on non-dealer institutions that may not be natural holders of collateral-eligible securities. In particular, these institutions may benefit less from netting positions in a CCP because they have fewer counterparties and they often have exposures that are not offsetting; that is, they tend to be in one 'direction'. In discussion, it was acknowledged that the model could usefully be refined further, and that taking the model to 'real' data would help to establish the economic significance of the results.

The second session was given over to the keynote address by Franklin Allen. Presenting joint work with Elena Carletti, Allen reviewed the academic literature on liquidity and funding markets. The paper describes how the academic community is refining its thinking in light of the crisis and highlights where important questions remain unanswered. While past crises have tended to be characterised by runs, the effectiveness of deposit insurance and other guarantees meant that deposits remained among the most stable forms of funding during the recent crisis. Instead, the crisis was largely characterised by the failure of interbank markets. Existing literature neither helped to predict nor manage this phenomenon. Since the onset of the crisis, a great deal of academic work has sought to deepen our understanding of the interbank market and explain observed developments. Allen also considers outstanding questions in the real estate market. He observes that the tendency for 'boom-bust' cycles in the real estate market was amplified in the crisis by the shift to securitised funding. Again, the literature in this area is not rich enough to fully explain what happened. Overall, it was acknowledged in discussion that, while the literature was catching up, much work remained to be done to explain developments during the crisis, and that we needed to be careful not to fall into the trap of 'fighting the last war'.

The third session examined the role of central banks more closely. The first paper, by Grahame Johnson and Eric Santor, presents a rich analysis of core funding markets. In the authors' framework, core funding markets are identified according to how central they are to the financial system, the absence of ready substitutes, and the propensity for contagion in the event of a disruption to their functioning. With reference to experience of the financial crisis, the paper proposes five principles for the design and implementation of central bank intervention. That is, intervention should be targeted, graduated and well designed, and it should aim to minimise unintended market distortions and mitigate moral hazard. In discussion, participants questioned where to draw the line when identifying core markets, but generally agreed that it was instructive to articulate a framework for central bank intervention.

A notable change in behaviour for some central banks since the onset of the crisis has been the pursuit of unconventional monetary policies. The second paper in the third session, by Morten Bech and Cyril Monnet, examines whether existing models can explain the stylised facts around how conditions in the interbank markets vary with the level of excess reserves, which are used as a metric for unconventional monetary policy. In particular, they note four facts: higher excess reserves drive overnight interbank rates towards the bottom of the interest rate corridor, reduce volatility and reduce market volume. Also, higher credit risk for an institution raises the overnight rate it pays. The authors develop a common framework to test the predictions of three models and find that introducing a 'directed search' mechanism for banks to trade reserves allows all four stylised facts to be explained.

The final paper in the session, by Morten Bech and Todd Keister, considers how central bank policy may need to adapt to accommodate the Liquidity Coverage Ratio (LCR) introduced under Basel III. The LCR is a means of promoting liquidity self-insurance in the banking sector by requiring that banks hold a minimum quantum of high-quality liquid assets (HQLA). In some jurisdictions, however – including Australia – there is insufficient HQLA. Accordingly, the Basel rules specify that a committed liquidity facility (CLF), offered by a central bank for a fee, is an acceptable alternative approach to meet the requirement. This paper examines the economics of such facilities, and in particular the incentives they create and how they should be priced. The authors conclude that an optimal pricing policy for a CLF will encourage banks to satisfy the LCR as far as possible using HQLA, while at the same time maintaining the liquidity premium in the market at a reasonable level.

The final two papers of the conference were presented in a session that aimed to draw links between liquidity and funding markets, and monetary and financial stability. The first paper, by Silvia Miranda Agrippino and Hélène Rey, examines funding flows, asset prices and macroeconomic outcomes in 'carry-trade' economies. The paper builds on the observation that some economies are susceptible to large cyclical inflows and outflows of capital, often motivated by a search for yield. Using data for a sample of relatively small open economies, the authors confirm the procyclicality of capital inflows to these economies, observing that these are highly correlated with a global 'risk' factor, proxied by the Chicago Board Options Exchange Market Volatility Index (VIX). The VIX is also correlated with risky asset prices in the recipient countries, including property prices. Much of the subsequent discussion centred around the validity of the VIX as a proxy for the global factor. The authors were encouraged to consider other volatility measures.

The final paper, by Prasanna Gai, Andrew Haldane, Sujit Kapadia and Benjamin Nelson, returns to the collateral theme from earlier in the conference. The authors explore the trade-offs in secured funding markets, drawing out the macroprudential risks associated with rising levels of asset encumbrance. A key concern – particularly where the extent of encumbrance is opaque – is that a run by unsecured creditors becomes more likely. The authors show that this channel is highly procyclical: as collateral values decline, secured creditors will demand more collateral, which further encumbers balance sheets and leaves fewer assets available for unsecured creditors. This in turn increases their incentive to withdraw funding. The paper considers potential policy responses, including disclosure of encumbrance, caps on asset encumbrance, and cyclical policies such as time-varying haircuts or liquidity requirements on secured funding transactions.

The policy panel drew together the discussion of the preceding day and a half. Panellists acknowledged that the crisis had revealed tensions and interdependencies for which the academic and policy communities were not prepared. An unprecedented response from governments and central banks prevented an even more severe outcome, and the deep and wideranging regulatory agenda pursued since the crisis aims to correct the worst shortcomings identified in the design of the financial system. Kevin Nixon stressed that the system remained in transition as regulatory reforms were implemented and that we didn't yet know what the eventual equilibrium would look like. Indeed, there was a risk associated with not fully understanding the combined effects of all the regulatory reforms in train. Richard Portes, by contrast, queried whether regulators were doing enough, and expressed the concern that industry lobbyists were succeeding in weakening regulators' resolve and watering down reforms. Jean-Pierre Danthine understood and appreciated the desire to see material regulatory change, and acknowledged that there was much more to be done. Taking the example of implementing the LCR in Switzerland, however, he demonstrated the complexity of the reform process and the importance of thinking through the issues carefully before proceeding with new regulation.

The Economics of Shadow Banking

Manmohan Singh*

1. Introduction

The past decade has witnessed rapid growth in financial intermediation that involves interaction between banks and non-banks. Coined under the rubric of 'shadow banking' the nexus between banks and non-banks is largely seen as a form of regulatory arbitrage. However, this is an incomplete view since there is genuine economic demand for these services. This paper attempts to explain the economics that support the demand for and supply of services in this market, the systemic risks that can arise, and regulatory and broader policy implications.[1]

To formulate a policy response to shadow banking, one needs to understand the 'nuts and bolts' of how these markets work. Shadow banking centres on the collateral intermediation function underpinning the plumbing of the financial markets. This includes the financial lubrication provided by intraday debits and credits, and cross-border payments of 'cash or cash equivalents' (i.e. money plus collateral) to meet margin and other obligations. Collateral underpins a wide range of financial transactions: secured funding (mostly provided by non-bank investors), repurchase agreements (or repos) and hedging (primarily with over-the-counter (OTC) derivatives). Since acceptable collateral is becoming increasingly scarce, a key shadow banking function is to mobilise and re-use collateral to support a large volume of transactions. Much of the 'capital' used in shadow banking, in the form of margins and over-collateralisation (via haircuts), does not make it onto the balance sheet. However, this capital remains 'shadowy' and not as easy to quantify as the Basel Committee's 8 per cent capital on the balance sheet for banks.

A globally integrated financial system needs to be able to manage counterparty risk. As aggregate economic activity rebounds and as regulations on the traditional banking system are tightened, the role of shadow banking will gain traction.

To the extent that many shadow banking activities have valid and valuable economic and financial market rationales, regulation should not be so strict as to undermine the benefits of shadow banking. However, this does not mean that a policy response is unnecessary, since systemic risk needs to be contained. In 2012, the Financial Stability Board (FSB) articulated an agenda to deal with regulatory weaknesses, spillovers and systemic risk in shadow banking (FSB 2012).[2] Short-term

---

* Responsibility for any errors rests with the author.

1 FSB (2011) defines shadow banking broadly as 'credit intermediation involving entities and activities outside the regular banking system'. While measures of shadow banking differ considerably, the system is large, comparable in size to traditional banking and continuing to grow.

2 Prior to the crisis, much of the discussion of shadow banking was on securitisation and the upgrade of assets, including: the use by banks of affiliated investment vehicles to offload credit risks (and economise on capital); credit and liquidity guarantees with too little provisioning; and investments in structured products where capital charges did not reflect underlying risks (Gorton and Metrick 2010; Kane 2012; Acharya, Schnabl and Suarez 2013). This paper will not repeat this literature but rather is forward looking and thus will focus on forthcoming issues.

wholesale funding markets remain vulnerable five years after the failure of Lehman Brothers. In July 2013, Governor Daniel Tarullo, Member of the Board of Governors of the Federal Reserve System, reiterated that 'a major source of unaddressed risk emanates from the large volume of short-term securities financing transactions in our financial system, including repos, reverse repos, securities borrowing, and lending transactions' (Tarullo 2012, 2013).

The analysis allows four components of a comprehensive policy response to be outlined: (i) addressing systemic risks within the shadow banking system; (ii) addressing demand-side pressures and how to accommodate a shortage of safe and liquid assets; (iii) dealing with 'puts' to taxpayers from shadow banks, the focus of much recent regulatory action; and, most importantly, (iv) considering potential macroeconomic, monetary and quasi-fiscal implications.

Section 2 outlines a basic analytical framework for understanding what the shadow banking sector is and how it interacts with the traditional banking system. Section 3 describes the role of the shadowing banking sector in recycling collateral and the implications for this function of the potential shortage of assets that can be used as collateral. It also discusses collateral use and re-use (or, velocity) and how it affects non-bank funding to the banking sector. Section 4 summarises views on the shortage of safe assets. In an era of quantitative easing (QE) and regulatory proposals demanding more safe assets, this section proposes increasing collateral velocity to bridge the gap between demand and supply. Section 5 introduces the role of central banks in the non-bank/bank nexus since they are now (and will be in the near future) a major player in the collateral market. Section 6 highlights the risks that may still be inherent in the structure of the shadow banking sector that may require taxpayer bailouts. Section 7 concludes with some policy suggestions on how shadow banking affects monetary policy, quasi-fiscal policy and financial stability.

2. Basic Analytical Framework

Bank credit to ultimate borrowers is either funded by the equity of the banking system or by the funding that non-banks (e.g. households, pension funds and insurers) provide to the banking system. Following Shin (2010), this can be depicted as

$$\sum_{i=1}^{n} y_i = \sum_{i=1}^{n} e_i z_i \left(\lambda_i - 1\right) + \sum_{i=1}^{n} e_i \tag{1}$$

where y_i denotes the total lending to ultimate borrowers by bank *i*. The first term on the right-hand side denotes the total funding to the banking sector provided by non-banks (or, outside claimholders), where e_i is the equity of bank *i*, z_i is the fraction of non-bank funding that bank *i* receives, and λ_i is the leverage of bank *i*. The second term on the right-hand side denotes the total equity of the banking system.[3]

The traditional view of a banking system is that total funding from non-banks (the first term on the right-hand side) is relatively 'sticky'. In other words, it is often assumed that non-bank funding to banks predominantly reflects households' deposits *only* (or M2), which grow steadily in line

3 This notation does not fully accord with current accounting and regulatory conventions. For example, from a regulatory point of view, until Basel III is implemented, leverage refers mostly to on-balance sheet leverage. Under Basel III, several off-balance sheet items will come onto balance sheets by 2017.

with evolution in household wealth (Adrian and Shin 2010; Shin 2010).[4] Thus, non-bank funding to banks is assumed to not vary much.

Under this assumption, rapid increases in the aggregate volume of credit supplied through the banking system must come via increased leverage (λ_i) which – due to the 'stickiness' of total non-bank funding and the stable nature of M2 – are assumed to come from increases in interbank claims.

This view, however, ignores the significant funding that banks receive from the asset management complex; this is not fully captured in monetary aggregates like M2. Even when household deposits are sticky, the presence of non-bank firms and intermediation through the shadow banking system allows leverage to rise quickly in both individual banks and the banking system as a whole.[5] In the United States, the gross volume of funding from non-banks that was intermediated by banks may have been as high as US$25 trillion and US$18 trillion at the end of 2007 and 2010, respectively. In other words, non-banks' funding to banks involves much more than just households and their deposits.

So, even with relatively stable M2, the banking system can become highly leveraged, not necessarily by increased interbank lending, but through the portfolio choices of the asset management complex. Unlike short-term household funds – which are primarily in M2 liabilities – short-term investments of asset managers are primarily in the form of non-M2 liabilities.[6] In turn, the supply of privately guaranteed non-M2 liquid assets is by and large a function of the aggregate volume of short-term claims.[7]

The term z_i in Equation (1) can be expressed as

$$z_i = z_h + z_k$$

where z_h is the fraction of funding that bank *i* receives from households, and z_k is the fraction of funding that bank *i* receives from non-bank financial institutions.

4 Adrian and Shin (2010, p 8) note that 'M2 … is a good proxy for the total stock of liquid claims held by ultimate creditors against the financial intermediary sector as a whole' and later demonstrate that M2 has been slow moving or stable over time, expanding 'by a factor of 2.4 since 1994'. Shin (2010, p 8) notes that '[t]he total debt liabilities of the banking sector to the household creditors can be expected to be sticky, and would be related to total household assets … For the purposes of short-term comparative statics, we could treat it as a constant'.

5 Leverage is typically measured on a gross basis and interbank lending on a net basis. As an example, suppose Bank A wants to buy a million dollars of securities from a non-bank firm using funding received from Bank B (on the basis of the collateral of the securities). Further suppose that Bank B refinances from Bank C and that Bank C in turn refinances with Bank D, itself funded by an ultimate non-bank saver (i.e. household or mutual fund). Assets of Banks A, B, C and D each rise by $1 million, for a total of $4 million – gross interbank lending/borrowing of $3 million and financing from non-banks of $1 million. Since capital has not changed, bank leverage goes up.

6 Since the money holdings of asset managers are ultimately the claims of households, it follows that households ultimately fund banks through both M2 and non-M2 instruments. It is important to note, however, that while households' *direct* holdings of M2 instruments reflect their own investment decisions, their *indirect* holdings of non-M2 instruments are *not* a reflection of their direct investment choices, but the portfolio choice and investment management techniques of their fiduciary asset managers.

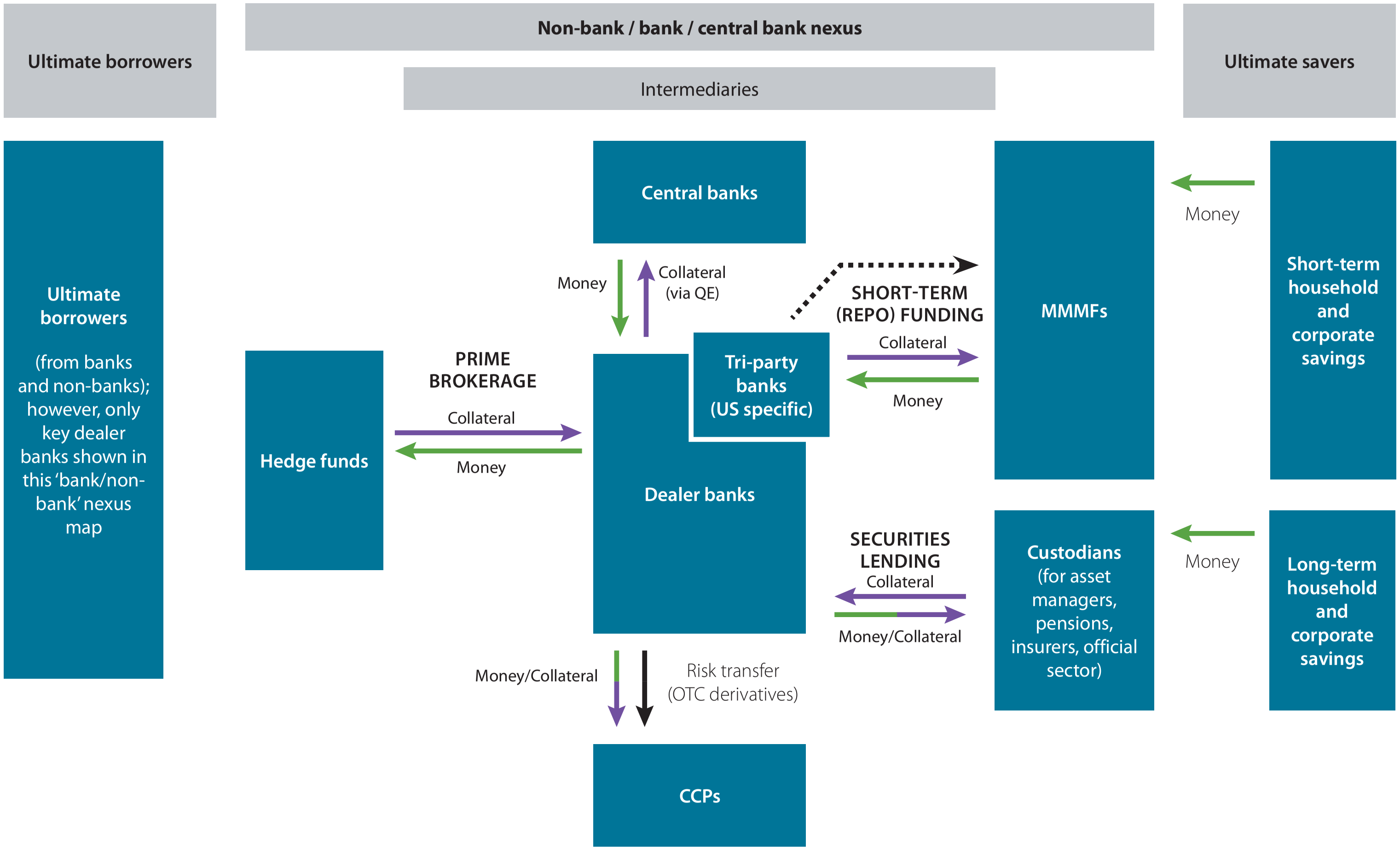
7 See Pozsar and Singh (2011) for another interpretation of *z*.

Figure 1 highlights the non-bank/bank nexus, which includes collateral velocity and leverage, that is key to understanding shadow banking.[8]

- **Ultimate borrowers** (Figure 1, left column), include corporations, households and government.
- **Ultimate savers** (Figure 1, right column), include *short-term* household and corporate savings and *long-term* investors through the asset management complex (insurance, pension funds).
- **Dealer banks**, which play a central role in intermediating collateral and money flows. These dealer banks connect the non-bank space, including recent central bank QE-type activities, and funnel collateral or money between various non-banks (money market mutual funds (MMMFs), hedge funds, pension funds, insurers, official sector accounts) and from non-banks to central banks.

8 There are other commercial banks (not shown in Figure 1) that are not active in collateral intermediation but connect ultimate savers to ultimate borrowers via syndicated loans, letters of credit, and traditional banking services. These are not the global systemically important financial institutions (G-SIFIs). Rather, they span the small, medium-sized and even global non-dealer banks. In the analytical framework described above, the business operations of these commercial banks (generally) do not interact with non-banks via derivatives, securities lending, repo agreements or prime-brokerage activities. Hence the z_i for commercial bank i will not be significant. However, the ultimate borrowers (y_i) will borrow from both types of banks.

Figure 1: The Financial Plumbing



Notes: Figure 1 is a snapshot of z or the non-bank/bank nexus explained in the analytical framework. The dealer banks depicted above are active in cross-border collateral intermediation. So z_i is important for dealer bank i. The ultimate borrowers also borrow directly from commercial banks. However, they are not shown in this figure as their interaction with non-bank is minimal; hence z_i is negligible.

3. Collateral Use and Re-use

Collateral provides the financial lubrication that allows intraday debits and credits to be made, and financial markets traditionally use 'cash or cash equivalent' (i.e. money plus collateral) to meet margin and other obligations. In addition, a great deal of short-term financing is generally extended by private agents against financial collateral. Financial collateral does not have to be rated AAA or AA; as long as the securities (i.e. debt or equity) are liquid, marked to market, and transferred under a legally enforceable cross-border master agreement, they will be considered 'cash equivalent'. Pledged financial collateral is difficult to map but is a key component of financial plumbing.

The collateral intermediation function of the shadow banking sector is likely to become more important over time. In the short term, increased counterparty risks (as evidenced during 2007–2008 and in Europe today) make secured funding more attractive. In the longer term, with more arms-length transactions in an increasingly integrated global financial system, market participants are seeking the security of collateral to underpin a wider range of claims. New regulations are also likely to increase the demand for collateral-based operations.

The use and re-use of pledged financial collateral facilitates financial transactions and contributes towards the supply of credit to the real economy. Analogous to the traditional money-creation process, i.e. the lending-deposit-lending process based on central bank reserves, there is a multiplier effect. Collateral is like high-powered money, where the haircut is equivalent to the reserve ratio, and the number of re-pledges (the 'length' of the collateral chain) is equivalent to the money multiplier. The aggregate volume of re-pledged collateral reflects both the availability of 'source' collateral as well as the re-use rate of source collateral. Although collateral-backed credit does not increase the money supply, it does affect the real sector and the monetary policy transmission mechanism (Singh 2013a).[9]

The stock of collateral and its velocity (the intensity with which it is re-used) are both fundamental to understanding the financial plumbing in the shadow banking world. Since the failure of Lehman Brothers in 2008, the increase in aversion to counterparty risk and related issues have led to a significant drop in pledged collateral among the major US and European globally active banks and this market is not rebounding. This stems from a decline in both the collateral that is pledged for re-use and the associated re-use factor.[10]

The volume of collateral transactions has declined over the five years since the start of the crisis, from US$10 trillion in 2007 to US$6.0 trillion in 2012, while the stock of collateral has declined from US$3.4 trillion to US$2.8 trillion (Table 1). The stock of collateral can decline as investors become more concerned about counterparty risk, making them less willing to lend securities and more content to leave collateral sitting safely in segregated accounts. It can also be affected by central bank measures, such as large-scale asset purchases, which drain good quality collateral from the

9 The term re-pledged is a legal term and means that the dealer receiving the collateral has the right to re-use it in its own name (i.e. the recipient takes title). Title transfer is essential to collateral velocity. In the bilateral pledged collateral market, contracts that span repo, securities lending, OTC derivatives and customer margin loans involve title transfer.

10 Since cross-border funding is important for large banks, the state of the pledged collateral market needs to be considered when setting monetary policy (Debelle 2012).

system, or a widening of the pool of collateral-eligible assets which increases the pledge-ability of these assets as collateral to the central banks (Singh and Stella 2012).

Table 1: Collateral
US$ trillion

Year	Sources			Volume of secured transactions	Velocity
	Hedge funds	Others	Total		
2007	1.7	1.7	3.4	10.0	3.0
2010	1.3	1.1	2.4	5.8	2.4
2011	1.3	1.05	2.35	6.1	2.5
2012	1.8	1.0	2.8	6.0	2.2

Sources: IMF staff estimates; The Risk Management Association; Singh (2011, 2012a)

Collateral velocity – defined as the volume of secured transactions divided by the stock of source collateral – is affected by counterparty concerns and general risk aversion (due to higher haircuts), which then manifest as restrictions on the re-use of collateral. The velocity of re-use is an important concept and a key determinant of z_i in Equation (1). Velocity can therefore change, like the velocity of money: it was 3 at end 2007, 2.4 at end 2010 and 2.2 at end 2012.

The collateral intermediation function of shadow banking is important within the financial system and, to the extent that it supports credit, it is also important for the real economy (although quantifying the economic importance is complex).[11] When collateral use drops, financial intermediation slows, with effects similar to the drying up of interbank markets (Adrian and Shin 2009; Singh 2012a). The velocity of re-use is an important concept and a key determinant of z_i in the analytical framework of Section 2. The next section discusses the potential for a shortage of collateral eligible assets and the options available to policymakers to resolve any issues.

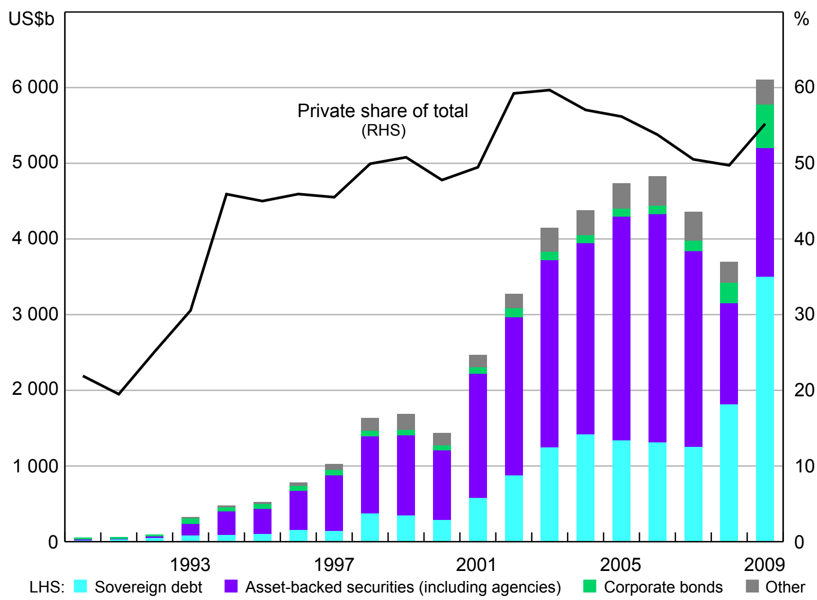
4. Shortage of Safe/Liquid Assets

In the lead up to 2007, there was an increase in demand for safe assets. However, the supply of truly safe assets is relatively price-inelastic. This made the equilibrium price of government-guaranteed safe assets very high (and their yields very low or negative), creating incentives for the system to create private AAA-rated assets (Figure 2).[12]

11 For example, a pension fund adept in securities lending may augment returns to its pensioners in the real economy. As another example, a hedge fund may bid for an IBM bond issue, since it has funds via its prime broker (in lieu of collateral posted). A higher number of bidders lowers IBM's cost of bond issuance, thereby benefiting the real sector.

12 As documented by Duffee (1996) and Greenwood, Hanson and Stein (2012), investors will pay a 'premium', i.e. accept a lower yield, for government-guaranteed securities, as they offer a preferred combination of safety and liquidity.

Figure 2: AAA Securities



Source: Bank for International Settlements

Accordingly, a number of academics and policymakers have advocated correcting situations of excess demand for safe assets directly by having the government expand the supply of safe, short-term liquid instruments to crowd out those supplied by the shadow banking system (Ricks 2011; Gourinchas and Jeanne 2012; IMF 2012). In their models, the government is in a better position than the private sector to issue safe assets due to its power to tax, and the authors suggest that any excess demand can be met by offering more short-term debt. This would reduce demand pressures to create potentially relatively less safe private assets and remove a major source of systemic risk.

However, adjusting the supply of short-term government debt can come with some challenges, particularly related to debt management. Authorities may have to depart from widely accepted minimal cost rules in debt management (Garbade 2007). By issuing more short-term paper than would otherwise be necessary, the government would also take on some interest rate and operational risks from the private sector. An alternative to the government issuing more 'safe assets' at a cost to debt issuance, or increasing private sector supply, would be to increase the velocity of good collateral (i.e. high-quality liquid assets (HQLA)).

There may be other conceptual and practical limitations to the effectiveness of demand-side policies. It is unclear whether it is appropriate for the government to engage in creating financial market assets with the sole purpose of catering to a particular investment clientele.[13] For example,

13 For example, Claessens *et al* (2012) argue that the supply of Treasury bills should increase to accommodate demand from MMMFs since there is a shortage of safe assets. Recall, the US Treasury discontinued 30-year bonds in the early 2000s due to a primary surplus in the Clinton years – the Treasury did not factor in the demand for duration coming from pension funds and insurers. It should also be noted that the role of government policy in fine-tuning debt issuance is diminished when debt levels are either high or capped (Greenwood *et al* 2012).

this may create moral hazard in that the private sector may come to expect that the government will accommodate its demand for specific types of assets.

5. New Entrants to Financial Plumbing: Central Banks

In recent years, the official sector has inadvertently absorbed good collateral and has become an integral participant in the non-bank/bank nexus. In particular, when central banks buy securities, for example via QE, one of the immediate effects is to increase bank deposits. In the United States, the Federal Reserve System (the Fed) has, in practical terms, bought securities from non-banks, not banks, and so QE has added to M2. Whether banks retain those additional deposits or convert them into other liabilities (or, by calling in loans, reduce or moderate the growth of their balance sheets) is an open question. This section discusses how QE-type efforts convert what had been HQLA (or good collateral) available to financial markets into additional bank liabilities (Singh 2013a).

5.1 Price of money and price of collateral

In some countries, such as the United States and the United Kingdom, the price of money and money market rates are not market-determined due to the payment of interest on excess reserves (IOER) at the central bank, which is available only to depository institutions. This creates a wedge between banks and non-banks that do not have access, and thus affects other short-end rates. For example, in the United States, the government-sponsored enterprises (GSEs) – that is, Freddie Mac and Fannie Mae – and other non-depository institutions are not eligible to deposit excess reserves at the Fed and thus do not have access to IOER. This has resulted in market segmentation and creates a wedge in money market rates because overnight rates for depository institutions cannot trade below the floor of the corridor, while the rates for non-depository institutions can. Thus the effective federal funds rate, which is calculated using all overnight transactions, can also fall below the floor.[14] This wedge between IOER and the effective federal funds rate is important; the federal funds rate was 9 basis points on 29 July 2013, quite some distance from expectations of an initial 25 basis points increase in policy rates. Compare this deviation of 16 basis points to the average daily absolute deviation of effective federal funds rate from their policy target of 3 basis points before the crisis (Stella 2013)!

Now consider collateral or repo rates. Recall that the collateral rate (or repo rate) is the rate at which cash is lent against collateral for an agreed tenor. It is agreed upon by the two parties at the 'start of repo'. Typically, a shortage of eligible collateral lowers repo rates; an abundance of collateral increases repo rates. Thus, the repo rate is a benchmark for collateralised transactions that underpin the financial plumbing between dealer banks and non-banks.

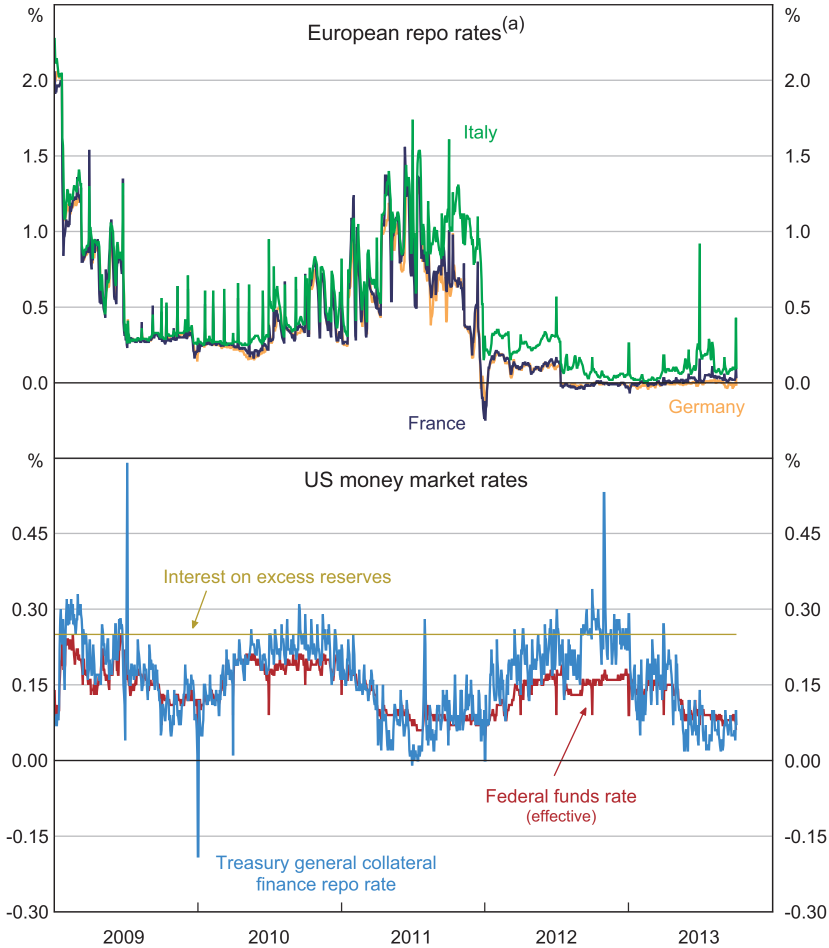
In theory, the price of 'good collateral' should not vary across assets except due to technical factors.[15] However, there is a wedge between comparable repo rates in the United States and the euro area (Figure 3). This is mainly because in the United States IOER and 'Operation Twist', which increased the supply of Treasury bills in 2012, have led to short rates remaining positive, whereas

14 Following the failure of Lehman Brothers, the Fed introduced IOER for depository institutions. This was intended to place a 'floor' (minimum bid) on short-term liquidity in the corridor system. See Bech and Monnet (this volume).

15 Technical issues include, among other things, 'home' bias, the relative liquidity/depth/size of euro area and US collateral markets, different QE policies, and cheapest-to-deliver collateral. See Fegatelli (2010) for a discussion of the euro area collateral market.

collateral/repo rates in some European countries, including Germany, France, the Netherlands, Denmark and Switzerland, have recently dipped below zero.[16]

Figure 3: General Collateral/Repo Rates



Note: (a) Volume-weighted average rate of general collateral and special bonds

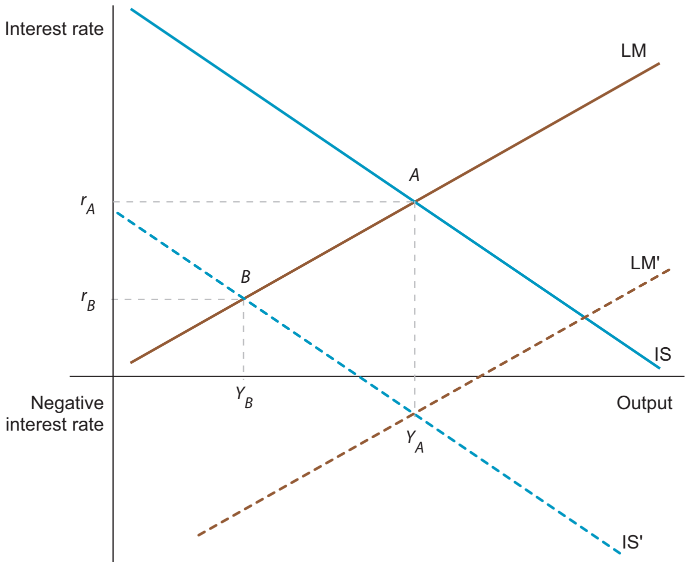
Sources: Bloomberg; Board of Governors of the Federal Reserve System; The Depository Trust & Clearing Corporation; ICAP

16 Siloed collateral has zero velocity by definition. Market sources indicate that good euro area collateral (including equity and corporate bonds) is being purchased by some central banks and therefore 'removed' from the market; this a drag on European Central Bank efforts to keep the collateral re-use rate high.

5.2 Collateral and monetary policy – via the IS-LM framework

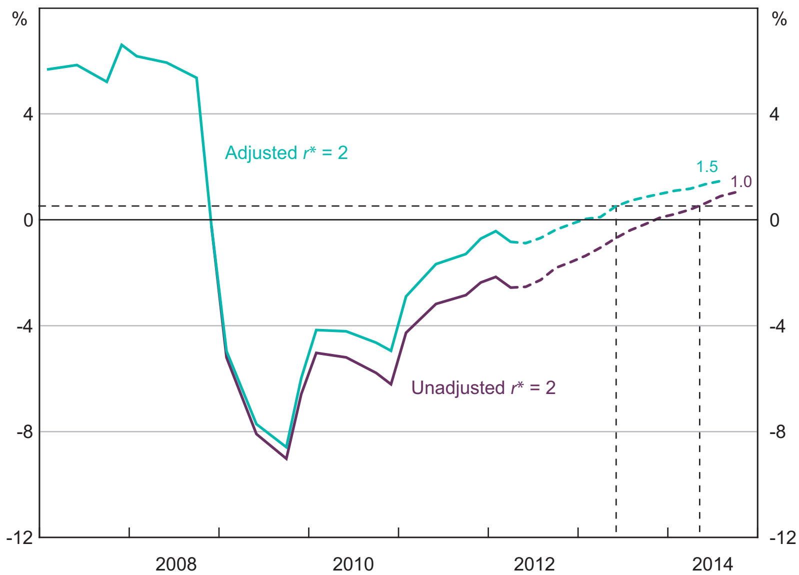
It is instructive to consider these developments using the classic textbook IS-LM framework. The recent collapse in financial collateral (by an estimated US$4–5 trillion), among other factors, has significantly shifted the IS curve in, lowering output to Y_B and decreasing the real interest rate (Figure 4). In recent years, QE efforts have shifted the LM curve to the right to accommodate this decline, until the LM curve eventually intersects with the IS curve at the initial output level, Y_A. The LM shift due to QE is sizeable (and continuing) and, combined with the inward shift of the IS curve, real interest rates may be well below zero. Due to distortions in money market rates (that are above zero in nominal terms), however, we do not see sub-zero real rates.

Figure 4: Contraction in Pledged Collateral Market and IS-LM Shifts



A recent speech by New York Fed President Bill Dudley suggests that the Fed's QE actions may have lowered nominal rates by an additional 150–200 basis points (Dudley 2012). So *unadjusted* real rates (i.e. if the Fed's balance sheet had remained at US$800 billion where it was around 2007) may be much lower than the *adjusted* real rates (due to the expanded balance sheet via QE) that are officially announced and that do not reflect the rate cuts embedded within QE (Figure 5). Given that the three most recent tightening cycles in the United States have averaged close to 400 basis points, this suggests the next tightening cycle could increase the policy rate to 2 per cent if it starts from minus 2 per cent. This suggests that the intersection of LM' and IS' is at Y_A and, analytically, in Figure 4, at approximately *minus* 2 per cent.

Figure 5: Real Interest Rates via Taylor Rule With and Without the Fed's Balance Sheet Adjustment



Notes: Dashed curves are Federal Reserve Bank of New York staff projections; output gap is measured by the unemployment gap; inflation is measured by the private consumption expenditure deflator

Source: Dudley (2012)

5.3 Central banks and repo markets

The past few years since the failure of Lehman Brothers have seen major central banks take out good collateral from markets and replace it with central bank balances (except the ECB which has provided central bank balances in return for bad collateral). Sooner or later, these balance sheets will *unwind* – either voluntarily when central banks reverse their policy stances, or involuntarily as the securities held by central banks mature or roll-off. Analytically, this will move the LM curve to the left. Simultaneously the rate of release of collateral (in lieu of money) will move the IS curve up. So an unwind of QE will increase both the (money) interest rate and the (collateral) repo rate.[17] As

17 There is likely to be an asymmetry between the pace at which the Fed acquired collateral from the market under QE and the pace at which it will unwind its holdings. It is useful to make the distinction between ownership and possession – this is, after all, the collateral market we're talking about. Treasury bonds and agency mortgage-backed securities have a number of different characteristics (e.g. fixed duration, credit quality, liquidity). These securities can therefore perform many different functions (markets can buy 'pure' duration; sell duration short; or transfer possession to meet collateral needs, etc). The Fed has been absorbing these securities from the market with the sound macroeconomic objective of taking duration out of the economy (the portfolio balance channel), but duration is a function of ownership, not possession. The Fed can't let the ownership of these securities go back to the private market until the economy is strong enough to handle the duration (which is why the Fed is likely to unwind its holdings only slowly). Duration, however, isn't the service that the market needs. The economy needs the collateral services that these securities can offer, which transfers with possession, not ownership. The Fed needs a way to transfer possession to the market without ownership. Current SOMA (System Open Market Account) lending doesn't fit the bill, as it is a Treasury-for-Treasury swap executed to cover shortages in specific issues. The Fed has therefore proposed a reverse-repo program for the unwind of its balance sheet (contingent on balance-sheet space at banks and non-banks, amid a tighter regulatory environment). Most of the securities bought under the QE program were acquired from non-banks (via the banks). Banks were largely a conduit for QE securities, and with Basel III regulations at the door, there is limited appetite for these securities. Whether non-banks will have balance-sheet space and appetite to buy them back is the key question.

both rates move up, policymakers will attempt to avoid creating a wedge between them. Looking forward, it will be paramount that central banks gain back their 'policy rate', typically set by macro factors underlying the Taylor rule, such as output gap, inflation forecasts, etc.

Since central bank balance sheets are presently bloated with collateral, some (e.g. the Fed) have envisaged an 'unwind' that may occur in parallel and overlap with the path of projected rate increases.[18] However, the collateral/repo rate will need to be contained below the policy rate to avoid inflationary dynamics.[19] Thus repo rates will remain an important gauge of market conditions when central banks unwind. Analogous to a coiled spring, the larger the QE efforts the lesser the control central banks may have on the 'wedge' between repo rates and their policy rate (e.g. IOER). This may have financial stability implications, since the repo curve is a good indicator for how collateral flows between banks and non-banks.

Box A: Pledged Collateral and Money Aggregates

Annual reports of large banks suggest that financial collateral (including collateral re-use) is sizeable and comparable with monetary aggregates such as M2 or broad money. Taking into account collateral use/re-use in addition to M2 or the monetary base in the United States, United Kingdom and euro area, financial lubrication was over US$30 trillion before the failure of Lehman Brothers (with one-third comprising pledged collateral).[1] The subsequent decline in both available collateral *and* associated re-use of collateral was sizeable (an estimated US$4–5 trillion). This is the difference between the magenta and blue lines in Figure A1. Note that the increase in M2 due to QE does not substitute for loss in financial collateral, especially if QE involves the purchase of good collateral, such as US Treasuries (Singh and Stella 2012).[2]

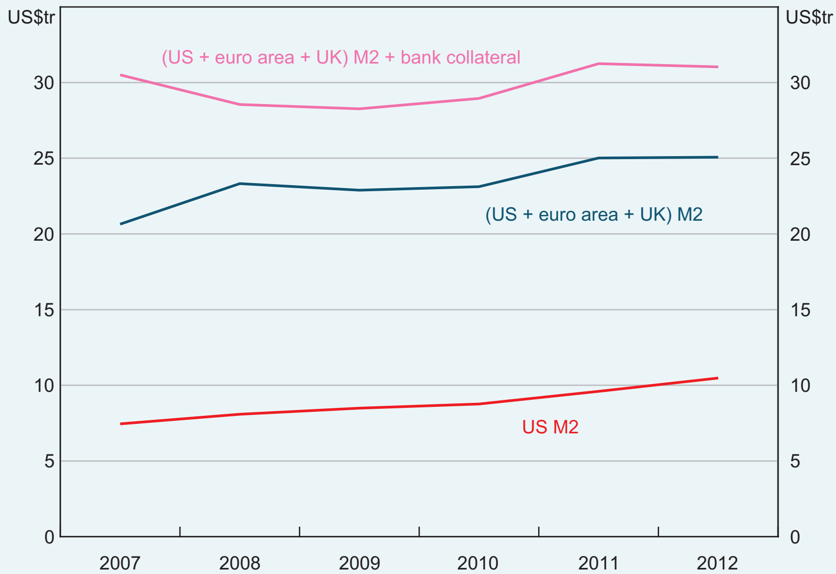
1 Japanese Government Bonds are generally not used in the cross-border pledged collateral market; hence, Japan is not included here.

2 Although there is a continuum between good and bad collateral, for simplicity we define C1 as good collateral in all states of the world, which can be converted to money (M) at no haircut. C2 is collateral that under normal market conditions is 'good' but loses its value in adverse states of the world. During a crisis, C1 (such as US Treasuries or Bunds) and M may continue to be acceptable at par, but all other securities cease to be liquid. To the extent that central banks merely substitute central bank money (M) for assets that have retained their value as collateral (C1), not much liquidity relief is achieved. In order to provide effective liquidity relief for the system, central bank money and liquid collateral must be injected against illiquid or undesirable assets (C2); the supply of unencumbered collateral has to increase. Central banks may become subject to a form of Gresham's Law (i.e. 'bad collateral will drive out good collateral from markets') if they prove slow or reluctant to loosen their collateral policies. Just as water finds its own level, collateral in the market domain generally finds its economic rent when it is pledged for re-use.

18 See exit strategy minutes as per FOMC (2011).

19 In the United States, the repo rate could differ from IOER depending on the rate of release of collateral via reverse repos, an important unwinding avenue that has been suggested by the Fed. If the Fed unwinds, the eligible counterparties for reverse repos (RRs) now include not only banks but also non-banks such as the GSEs and selected MMMFs. The repo rate will be determined by the size of RRs, along with the broader supply and demand conditions in the market. A number of regulatory initiatives under the rubric of shadow banking, primarily in the United States, will influence this process. These include, among others, altering the operating model of the MMMFs by removing the requirement to maintain a constant net asset value (NAV) and reforming the GSEs and the tri-party repo system. The balance sheet capacity of the 'shadow banking' system is, however, crucial if collateral needs to be unwound from central banks, given constraints on banks' balance sheets arising from Basel III capital, leverage and liquidity ratios. The Fed's trial reverse repo program is largely between the Fed and non-banks, which cannot rehypothecate the collateral they receive. The Fed thus controls collateral velocity, which effectively prevents repo rates from going over the interest rate paid on excess reserves. Even if there were sufficient balance sheet space, the ability of the Fed to engage in RRs could be limited as sizeable RRs could lead repo rates to significantly exceed the IOER, in turn generating inflationary dynamics or expectations thereof. Therefore, a balance will need to be struck between the price of money (IOER) and the price of collateral (repo rate) (Singh 2013b).

Figure A1: Financial Lubrication – Money and Collateral



Note: Estimates for 2012
Source: Singh (2013b)

The 'kinks' in the blue line in Figure A1 show M2 expansion due to QE. As at the end of 2012, overall financial lubrication (M2 + bank collateral) had rebounded to approximately US$30 trillion, but the 'mix' is more in favour of money (around 80 per cent of financial lubrication). Not only does money have lower velocity than pledged collateral, but much of it 'sits' as excess reserves with central banks (Singh 2011). Thus a rebound in the pledged collateral market may be more effective in easing liquidity constraints in financial markets than further QE. For example, the Fed's balance sheet has over US$1.8 trillion in excess reserves of large banks that does not contribute fully towards financial lubrication; these reserves can circulate in the interbank market, but cannot circulate between banks and non-banks. More importantly, the net cost or benefit of QE will become apparent when central banks address the trade-offs that need to be made in the unwind of QE securities on their balance sheets (or, when they elect not to unwind but instead to continue to 'carry' the collateral until it matures).

6. Some 'Puts' that have Remained at Large

In this section – an intended detour – we highlight the key non-banks that, due to their interconnectedness with the dealer banks, may (again) benefit from taxpayer support during the next financial crisis, despite attempts to rein in such 'puts'. What are these puts and why do they continue to exist? We discuss the typical players in the shadow banking literature that may access the 'puts': hedge funds, money market funds, central counterparties (CCPs) that will inherit OTC derivatives from dealer banks, and the tri-party repo entities (specific to the United States).

Providing puts, *ex ante*, for fear that the *ex post* bailout may be even more expensive encourages moral hazard and potential regulatory arbitrage. The key non-banks that engage with dealer banks in the shadow banking system are identified in Figure 1.

6.1 Hedge funds

One source of systemic risk (and risk to the public safety net) in collateral intermediation is the liquidity exposure of dealer banks to customers such as hedge funds. Dealer banks routinely use some collateral obtained from customers (e.g. rehypothecation of collateral received from hedge funds) for their own funding. A customer withdrawal may then have liquidity implications for the dealer bank, which will have to find new sources of collateral or liquidate its own positions (Duffie 2010). Runs by prime brokerage clients (typically hedge funds) demanding the return of their collateral were a major source of instability for dealer banks in 2008 (including all stand-alone US investment banks, such as Bear Stearns, Lehman Brothers and Merrill Lynch), ultimately leading to large central bank and government support measures. Now, new regulations monitoring large non-banks are in place (in the United States) and non-bank SIFIs are also being designated by other regulators.[20] Since the failure of Lehman Brothers, the Financial Services Authority (now the Prudential Regulation Authority and the Financial Conduct Authority) has also come a long way in articulating the UK's rehypothecation rules to hedge funds domiciled in its jurisdiction.

6.2 Dealer banks' non-depository affiliates

The 'puts' to the safety net are especially significant when a dealer bank is also a depository institution. This creates the scope to shift risks between the depository and non-depository parts of the business (Singh 2012b), which potentially subsidises shadow banking activities by reducing the funding cost.[21] Such conglomeration also creates conflicts and regulatory challenges, and increases risks to the taxpayer.[22] Yet, to date there is no comprehensive framework for regulating broker-dealers that is as well-articulated as the one that exists for banks.[23] Thus, systemic risks and puts to the safety net from dealer banks are likely to persist.

20 See Auer (2012). In the United States, the SEC's Rule 13c3 and Regulation T cap use of client funds by dealer banks. The United Kingdom has no such caps.

21 For example, in the United States, after Bank of America and Merrill Lynch merged, the OTC derivatives book of Merrill Lynch was 'moved' to the depository part of the merged entity. As a consequence, taxpayers may now provide a stronger backstop to the bank's overall derivatives activities.

22 Since the crisis, all dealer banks have had access to central bank liquidity facilities through related commercial banks, even though the depository part can represent as little as 5 per cent of the group's overall balance sheet (the highest is 60 per cent; see Singh (2012b)). This offers stability of funding, but increases moral hazard, as a dealer bank can shift risky assets to its bank subsidiary. More generally, dealer banks may have both the incentive and the capacity to increase risks in more extreme ways than do commercial banks. The financial crisis has made it clear that the regulation and supervision of broker-dealers was not sufficiently rigorous, and orderly resolution remains a challenge.

23 In the United States, the Dodd-Frank Act gives authorities powers to move a systemically important broker-dealer under the supervision and regulation of the Federal Reserve System. This may strengthen supervision by making it more comprehensive, but it does not address *how* to effectively regulate a dealer bank – that is, a broker-dealer that is an integral part of a banking group. Note that in the United States and elsewhere, while the safety net can extend to the whole SIFI, the broker-dealer operations can dwarf its banking part; for example, deposits of US and EU SIFIs – that is, the bank part – are often less than a third of the overall assets of the SIFI in the bank holding company. Similarly, while the Dodd-Frank Act enables an orderly liquidation of a dealer bank by the Federal Deposit Insurance Corporation, the precise processes have neither been fully articulated in theory nor tried in practice. At the same time, the Dodd-Frank Act has tightened the rules of lender-of-last-resort support to non-banks (Tucker 2012). Individual firm assistance is no longer available, although broad-based lending programs are still allowed in systemic crises, subject to approval by the Treasury Secretary.

6.3 Money market mutual funds (MMMFs)

There is also need for progress on MMMFs. Although smaller than before the financial crisis, the US money fund industry remains systemic and fragile. It offers 'redeemable at par' guarantees that cannot, as the crisis demonstrated, be supported in times of stress when asset values drop. In the crisis, this necessitated government support (McCabe 2011). Reforms currently being contemplated include lowering the average asset maturity of MMMFs, introducing capital requirements, requiring a floating NAV (as is largely the case in Europe), and using two-class claims on assets (one redeemable at par and the other contingent on the NAV). Choices are still to be made. In the meantime, MMMFs remain a significant source of systemic risk: in the United States, the government might (again) be forced to step in to limit the spillovers from a run as happened in 2008 (McCabe *et al* 2012). Interestingly, constant NAV in Europe is only allowed for short-term MMMFs (Ansidei *et al* 2012); these MMMFs operate with a very short weighted-average maturity (WAM) and weighted-average life (WAL) – the logic is sound that anything beyond short term should not be constant or 'par' (Ansidei *et al* 2012).

6.4 Qualified financial contracts

Qualified financial contracts (QFCs) take the form of derivatives and repos. Prevailing legal rules, such as the 'safe harbour' provision, allow some QFCs to be exempt from 'automatic stay' during bankruptcy, i.e. they are prioritised in reorganisation because they are deemed to be too interconnected with financial markets and any reformulation in bankruptcy could be disruptive. This exemption reduces market discipline and effectively subsidises the contracts' counterparties (dealer banks and the wider shadow banking system) at a cost to other creditors and the public safety net. While there is little to suggest that legal changes are imminent, recent studies highlight that the exemption status might not be economically justified (Bliss and Kaufmann 2005; Bolton and Oehmke 2011; Summe 2011).

- *OTC derivatives move to CCPs*. At the G20 meeting in Pittsburgh in 2009, it was decided that a critical mass of dealer banks' derivative-related risks would be moved to CCPs (which were until then viewed under the rubric of payment systems). This is a huge transition, primarily to move the risk from OTC derivatives outside the banking system. These new entities may also be viewed as 'derivative warehouses', or concentrated 'risk nodes' of global financial markets.[24] On average, each of the key dealer banks in Figure 1 carried about US$100 billion of derivative-related tail risk around Lehman's demise – this is the cost to the financial system from the failure of a dealer bank, where tail risk is measured by 'residual' derivative liabilities of a dealer bank (i.e. after netting and collateral – see Appendix A for details). Yet, instead of addressing the derivatives tail risk, the present regulatory agenda is focused on offloading

24 There are many proposals on trying to unwind SIFIs; it is a difficult (if not an impossible) task. So creating new SIFIs such as CCPs should be backed by sound economics.

all (or most) of the derivatives book to CCPs (Singh 2010).[25] CCPs have also been incorrectly regarded as utilities.[26]

- *Tri-party repo*. A distinct part of the collateral intermediation process, the tri-party repo (TPR) market, can present a different set of systemic risks. TPR is a major source of wholesale funding for banks and dealer banks, especially in the United States, where volumes approach US$1.8 trillion (down from US$2.7 trillion in 2007). In the US TPR market, one of the two intermediaries (either JPMorgan or Bank of New York) facilitates repo operations between counterparties, some of which are primary dealers, by providing intra-day overdraft facilities. Reforms to TPR are in motion, but under current arrangements the intraday position constitutes a risk to the intermediaries – and indeed is the reason Bank of New York is designated a SIFI. This highlights the 'put' faced by taxpayers. Since the TPR market differs from the bilateral pledged collateral market (which is truly mark-to-market and is the main subject of this paper), Appendix B describes the TPR market more fully. In continental Europe and the United Kingdom, TPR activity has increased in recent years to roughly €1.1 trillion, largely due to multinational companies keeping money overseas and recent counterparty risk concerns regarding large banks. Four tri-party agents intermediate this market: Euroclear and Clearstream, two 'utility-type' systems owned by users or a stock exchange, and Bank of New York and JPMorgan.

7. Policy and Macro Implications of Shadow Banking

Shadow banking is highly *procyclical*, which may have adverse real-sector consequences. For example, secured lending and repos rely on mark-to-market prices and margins/haircuts that adjust over the financial cycle; in the extreme, some collateral may become unacceptable during periods of turmoil. Also, shadow banking services give rise to greater financial system interconnectedness, which may help to reduce idiosyncratic risk through diversification but also exposes the system to spillovers in the event of large shocks (Acemoglu, Ozdaglar and Tahbaz-Salei 2012). The merit of proposals to reduce procyclicality via *ex ante* haircut schedules is not clear; this will be impossible to implement in bilateral collateral agreements as it can distort market-based price-setting for pledged collateral – the essence of financial plumbing![27]

Shadow banking is likely to have important interactions with *monetary policy*. Just as interest rate transmission can be impaired if the banking system is weak, the broader channels of monetary policy transmission depend on well-functioning capital markets, including shadow banking.

25 At a hearing of the House Committee on Financial Services, former FDIC Chair Shelia Bair testified to being 'surprised at the lack of concern over the designation of "financial market utilities", and particularly Section 806 which permits the Federal Reserve to provide safety net access to designated financial market utilities' (Bair 2013).

26 The revenue/benefits from OTC derivatives come from three sources: the origination fee *plus* netting on books *plus* the clearing fee. Banks will still keep all of the origination fee, *plus* some of the netting (from OTC derivatives that do not clear). A utility has two characteristics: (a) government backstop but (b) at negotiated 'economic rents'. So for CCPs to be utilities, all three revenue components identified above (which comprise the total economic rent) should be negotiable. But banks will never forego the origination or structuring fee; this is the biggest piece. The negotiation between regulators and banks is such that this fee will remain undisclosed – usually buried under the line item FICC (fixed income, currency and commodities) of their annual reports. Regarding CCPs as utilities is not appropriate unless they control the full spectrum of 'economic rents'.

27 Credit Support Annexes that accompany OTC derivative contracts, or master agreements that underpin cross-border repo and securities lending are privately negotiated bilateral agreements in which regulators should not intervene. Such contracts include the 'legal wheels of title transfer' and are designed to make financial collateral akin to money so that market participants can settle obligations (e.g. accounts, margins) using cash or cash equivalents.

The state of private, safe asset supply and the stock and velocity of collateral can therefore affect monetary policy transmission, with macroeconomic consequences. And monetary policy can affect risk-taking in shadow banking. When the interest rate is low, a steeper yield curve that increases the pay-off to maturity transformation and risk-taking can trigger an expansion of shadow banking activity, potentially leading to financial fragility (Adrian and Shin 2010; Singh and Stella 2012).

And, during crises, shadow banking may require public support, with possible *fiscal* implications.[28] During and after the financial crisis, the Fed had to support dealer banks and MMMFs via various facilities. While in some cases ultimate fiscal implications were limited, the contingent liabilities and risks of such operations were significant. Unless the systemic risks in shadow banking are addressed, these contingent liabilities (or 'puts') will remain in place, with perhaps larger actual costs in future crises.

Addressing risks in the shadow banking system is a work in progress for regulators and policymakers, and research has yet to catch up fully with the issues (see Appendix C).[29] Current regulatory approaches are actively pushing banks away from short-term, secured, wholesale funding markets and giving them incentives to issue more deposits and term funding. The likely result would be that riskier activities move outside the banking system (proprietary desks, hedge funds, and OTC derivatives to CCPs, to name a few), and into the shadow banking world.

Also if there is a shortage of safe/liquid assets, collateral transformation is likely to fill the void, but this will increase the nexus between banks and non-banks. As new regulations take effect, the demand for HQLA is likely to be accommodated by the 10–15 dealer banks that intermediate between banks and non-banks (Figure 1). This would entail 'connecting' clients (such as pension funds) that have good collateral with, for example, a hedge fund that does not have good collateral but needs to post collateral acceptable to a CCP. In general, central banks, sovereign wealth funds, and long-term asset managers require collateral that has low volatility, but is not necessarily highly liquid. These entities should be net providers of liquidity to the financial system. On the other side are banks, hedge funds and mutual funds that have a dramatically shifting need for liquid, 'good' collateral. So a market for collateral upgrades, or collateral transformation, in theory, could work (if not constrained by leverage and liquidity ratios). It should be noted that collateral transformation will further 'interconnect' the financial system. Thus, going forward, understanding and correctly mapping the shadow banking system will become even more important for policymakers.

28 As the rate cycle will increase from near zero rates, a higher monetary policy rate will also increase *quasi-fiscal* costs (for the Fed and Bank of England that provide interest on excess reserves).

29 However, synonymous with the assumption that shadow banking is a pejorative term, much of the collateral intermediation is assumed to be risky by financial regulators.

Appendix A: Over-the-counter Derivatives – Risk Transfer from Banks to CCPs

OTC derivatives markets straddle regulated systemically important financial institutions and the shadow banking world. Recent regulatory efforts focus on moving OTC derivatives contracts to CCPs. A CCP will be collecting collateral and netting bilateral positions. While CCPs do not have explicit taxpayer backing, they may be supported in times of stress. For example, the US Dodd-Frank Act allows the Federal Reserve System to lend to key financial market infrastructures during times of crisis. Even in the absence of clearing mandates, incentives to move OTC contracts could come from increasing bank capital charges on OTC positions that are not moved to CCPs (BCBS-IOSCO 2012).

The notional value of OTC contracts is about US$600 trillion, but while much cited, that number overstates the still very sizeable risks. A better estimate may be based on adding 'in-the-money' (or gross positive value) and 'out-of-the money' (or gross negative value) derivative positions (to obtain total exposures), further reduced by the 'netting' of related positions. Once these are taken into account, the resulting exposures are currently about US$3 trillion, down from US$5 trillion (see Table A1). However, when a dealer bank fails, its 'out-of-the money' positions are the real risk to the remaining counterparties (of the failed bank) who are *de facto* unhedged. Thus from the perspective of reducing taxpayer liability, exposure to dealer banks' 'out-of-the money' positions needs to be eliminated (which would be half the BIS figures shown in Table A1; Singh (2011)).

Another important metric is the under-collateralisation of the OTC market. The BIS estimates that the volume of collateral supporting the OTC market is about US$1.9 trillion. Assuming a collateral re-use rate between 2.2 and 3.0, the dedicated collateral is some US$700–900 billion. Some counterparties (e.g. sovereigns, quasi-sovereigns, large pension funds and insurers, and AAA corporations) are often not required to post collateral. The remaining exposures will have to be collateralised when moved to a CCP to avoid creating puts to the safety net. As such, there is likely to be an increased demand for collateral worldwide.

Table A1: Under-collateralisation in the OTC Derivatives Market

US$ billion

	Gross market value								
	2008	2009		2010		2011		2012	
	H2	H1	H2	H1	H2	H1	H2	H1	H2
Total	35 281	25 314	21 542	24 673	21 296	19 518	27 285	25 392	24 740
Foreign exchange contracts	4 084	2 470	2 070	2 524	2 482	2 336	2 555	2 217	2 304
Interest rate contracts	20 087	15 478	14 020	17 533	14 746	13 244	20 001	19 113	18 833
Equity-linked contracts	1 112	879	708	706	648	708	679	645	605
Commodity contracts	955	682	545	457	526	471	487	390	358
Credit default swaps	5 116	2 987	1 801	1 666	1 351	1 345	1 586	1 187	848
Unallocated	3 927	2 817	2 398	1 788	1 543	1 414	1 977	1 840	1 792
Gross credit exposure[(a)]	5 005	3 744	3 521	3 578	3 480	2 971	3 912	3 668	3 626

Note: (a) Gross market values have been calculated as the sum of the total gross positive market value of contracts and the absolute value of the gross negative market value of contracts with non-reporting counterparties; gross credit exposure is after taking into account legally enforceable bilateral netting agreements

Source: Bank for International Settlements

Appendix B: The Tri-party Repo Market

A tri-party repo (TPR) operation is an arrangement whereby a clearing bank acts as an intermediary for two repo counterparties. Around 50 to 70 per cent of repo operations in the United States are cleared using TPR, with recent volumes approaching US$1.8 trillion, much below the US$3 trillion in 2008.[30] The TPR market is a major source of wholesale funding for banks and dealer banks. The US market is serviced by two clearing banks, Bank of New York and JPMorgan, both determined 'systemic' by the FSB. Pledged collateral is held with custodians and cannot be re-pledged. The TPR arrangement has several advantages as it allows market participants to exchange collateral baskets, and also to outsource risk management (haircut calculation, margin calls, and substitution), pricing, and other ancillary tasks.

A distinguishing feature of the US TPR market is the daily unwind process. Borrowers want to have access to their pledged securities for routine daily trading purposes. This is enabled by the daily unwind, where at the start of the trading day collateral is returned to borrowers and cash to lenders, even if these were pledged under term transactions. Collateral and cash are then returned to the clearing bank before close of business. Since borrowers nevertheless have financing needs during the day, a clearing bank may extend intraday overdrafts on an unsecured basis (although regulators may require that banks call for collateral to support such overdrafts). This means that risks associated with lending are fully transferred twice during a full day: they are with ultimate lenders and secured overnight, and with the clearing bank and *unsecured during the day*.

The unwind process creates multiple risks. Clearing banks carry large-scale unsecured exposures relative to their capital. Since money is returned to them daily, the lenders see their position as short-term and money-like, even for term contracts. Given counterparty risk, however, the arrangement is inherently as vulnerable as other private safe asset arrangements, and indeed only official sector support helped avoid a run during the financial crisis similar to that experienced by prime money market mutual funds.

Current regulatory efforts are focused on limiting the duration of intraday credit by pushing the unwind to later in the day and improving intraday collateral management (Copeland, Martin and Walker 2010). Still, the intraday exposures remain large (of up to $100 billion on average per counterparty) and operationally difficult to reduce. This may preclude an unwinding of the role played by Bank of New York and JPMorgan – hence the TPR market may remain a 'put' to taxpayers. In continental Europe and the United Kingdom, TPR activity has increased in recent years to roughly €1.1 trillion due to multinational/corporate treasuries keeping money overseas and counterparty risk concerns regarding large banks. The key agents, Euroclear and Clearstream, do not provide intraday financing.

30 The bilateral pledged collateral market is not trivial. For example, hedge funds (HF) are increasingly funding themselves via repo. HF repo is estimated (on average) at about US$750–900 billion (Singh 2012b); given that UK hedge funds are about 25 per cent of the market – the US market accounts for about US$600 billion and the rest of the world for the balance. If the present size of the TPR market is US$1.8 trillion, and HF repo in US is about US$600 billion, then without considering securities lending, TPR is about 70 per cent of the repo market. However, securities lending is akin to repo (as legally they are very similar). Estimates of US securities lending is about US$800 billion; Europe is about US$200 billion. Thus the non-TPR market may be 45 per cent of overall repo-like activities (which is US$1.4 trillion/US$3.2 trillion).

Appendix C: Flow of Funds Data and Limitations

Banking sector and other financial data are captured in flow of funds (FoF) statistics, such as those produced by the US Federal Reserve System. Yet aspects that describe the banking sector's nexus with the non-banks are not covered by the FoF statistics. This short appendix attempts to highlight some of the salient aspects of the US FoF statistics to show that, even in mature markets like the United States, there are 'data gaps' in financial statistics that need to be complemented by a rigorous analysis of off-balance sheet statistics, and linkages with other sectors that are outside the regulatory perimeter.

First, special investment vehicles, off-balance sheet entities, were sizeable ahead of the 2007–2008 financial crisis. Although they are picked up in the FoF data, these data are aggregated. Presently, there is no way of using FoF data to trace back the banking sector's off-balance sheet liabilities to asset-backed commercial paper (ABCP) and MMMFs. Hedge funds' holdings of financial assets are buried in the FoF data on the 'household' sector. By aggregating and netting across all banks, the FoF loses relevant information. For example, securities lending on line 130 of the FoF is shown 'net' in line 20, and thus would not highlight a large positive build-up of exposure in, say, Bank X, and a negative build-up in, say, Bank Y. Thus there are limitations in using the FoF to detect early warning signals of stress in the banking sector.

Second, derivatives market developments are also difficult to track in the FoF. Financial statements do not provide the under-collateralisation (or margin shortfall) of derivative positions. Further, entities book their derivatives transactions differently. Among the recent additions to the 'banking community', Goldman Sachs maintains most of its plain vanilla derivatives books in the bank, while its equity and commodities derivatives are conducted out of the brokerage subsidiary. In the case of Morgan Stanley, most of its (notional) derivatives positions were still being conducted outside the commercial bank. The FoF accounts presently only reflect the flow of savings and investment of an economy. Derivatives unbundle risks associated with the securities that transmit the flow of savings and investments. To adequately track the workings of modern financial systems, the FoF will ultimately have to include 'satellite' accounts that track the flow of risks and collateral.

Third, more granularity is needed in the breakdown of short-term money market instruments. FoF data use the term 'open market paper' to capture money market instruments such as financial, non-financial and ABCP, Treasury bills, agency discount notes, etc. Not only is the breakdown of short-term instruments insufficiently granular, but it is impossible to track important details regarding holdings of short-term instruments (e.g. money funds', securities lenders' or corporate Treasurers' holdings of short-term investments). In summary, instruments of maturity transformation and the holders of risks related to maturity transformation are close to impossible to track through the FoF accounts.

Fourth, bank holding companies such as Citibank, JPMorgan, Deutsche Bank, Goldman Sachs and Morgan Stanley are not fully reflected in banking statistics. FoF shows all elements of the holding company (bank, dealer, asset manager, etc) but 'separates' the holding company's balance sheets and then aggregates all banks in one sheet; all dealers in another sheet, etc. This aggregation loses the overall picture of the holding company; hence the need to go back to the banks' 10Q/10K returns to see the build-up of all business positions of the bank holding company from its various components under one roof.

Overall, non-bank linkages with the banks are not fully captured in FoF statistics. Thus FoF data need to be augmented by other information that is usually buried in the footnotes to financial statements.

References

Acemoglu D, A Ozdaglar and A Tahbaz-Salei (2012), 'Systemic Risk and Stability in Financial Networks', unpublished manuscript, Massachusetts Institute of Technology.

Acharya VV, P Schnabl and G Suarez (2013), 'Securitization without Risk Transfer', *Journal of Financial Economics*, 107(3), pp 515–536.

Adrian T and HS Shin (2009), 'Collateral Shortage and Debt Capacity', unpublished manuscript.

Adrian T and HS Shin (2010), 'The Changing Nature of Financial Intermediation and the Financial Crisis of 2007-09', Federal Reserve Bank of New York Staff Report No 439, rev April.

Ansidei J, E Bengtsson, D Frisson and G Ward (2012), 'Money Market Funds in Europe and Financial Stability', European Systemic Risk Board Occasional Paper Series No 1.

Auer L (2012), 'Testimony of Deputy Assistant Secretary Lance Auer', Testimony before the House Financial Services Financial Institutions Subcommittee Hearing entitled 'Implementing Title I of the Dodd-Frank Act: The New Regime for Regulating Systemically Important Nonbank Financial Institutions', Washington DC, 16 May.

Bair S (2013), 'Testimony of Sheila C. Bair Chair of the Systemic Risk Council and Former Chair of the Federal Deposit Insurance Corporation', Testimony before the House Committee on Financial Services Hearing entitled 'Examining How the Dodd-Frank Act Could Result in More Taxpayer-Funded Bailouts', Washington DC, 26 June.

BCBS-IOSCO (Basel Committee on Banking Supervision and Board of the International Organization of Securities Commissions) (2012), *Margin Requirements for Non-Centrally-Cleared Derivatives*, Consultative Document, Bank for International Settlements, Basel.

Bliss RR and GG Kaufman (2005), 'Derivatives and Systemic Risk: Netting, Collateral, and Closeout', Federal Reserve Bank of Chicago Working Paper No WP2005-03.

Bolton P and M Oehmke (2011), 'Should Derivatives be Privileged in Bankruptcy?', NBER Working Paper No 17599.

Claessens S, Z Pozsar, L Ratnovski and M Singh (2012), 'Shadow Banking: Economics and Policy', IMF Staff Discussion Note SDN/12/12.

Copeland A, A Martin and Michael Walker (2010), 'The Tri-Party Repo Market before the 2010 Reforms', Federal Reserve Bank of New York Staff Report No 477.

Debelle G (2012), 'On Europe's Effects on Australian Financial Markets', Address to Bloomberg Seminar, Sydney, 14 February.

Dudley B (2012), 'Conducting Monetary Policy: Rules, Learning and Risk Management', Remarks at the C. Peter McColough Series on International Economics, Council on Foreign Relations, New York, 24 May.

Duffee GR (1996), 'Idiosyncratic Variation of Treasury Bill Yields', *The Journal of Finance*, 51(2), pp 527–551.

Duffie D (2010), 'The Failure Mechanics of Dealer Banks', *The Journal of Economic Perspectives*, 24(1), pp 51–72.

Fegatelli P (2010), 'The Role of Collateral Requirements in the Crisis: One Tool for Two Objectives', Banque Central du Luxembourg Working Paper No 44.

FOMC (Federal Open Market Committee) (2011), 'Minutes of the Federal Open Market Committee June 21–22, 2011', Board of Governors of the Federal Reserve System, Washington DC.

FSB (Financial Stability Board) (2011), 'Shadow Banking: Scoping the Issues', April.

FSB (2012), 'Strengthening Oversight and Regulation of Shadow Banking: An Integrated Overview of Policy Recommendations', Consultative Document, 18 November.

Garbade KD (2007), 'The Emergence of "Regular and Predictable" as a Treasury Debt Management Strategy', Federal Reserve Bank of New York *Economic Policy Review*, 13(1) pp 53–71.

Gorton G and A Metrick (2010), 'Regulating the Shadow Banking System', *Brookings Papers on Economic Activity*, Fall, pp 261–297.

Gourinchas P-O and O Jeanne (2012), 'Global Safe Assets', BIS Working Paper No 399.

Greenwood R, SG Hanson and JC Stein (2012), 'A Comparative-Advantage Approach to Government Debt Maturity', Harvard Business School Working Paper No 11–035.

IMF (International Monetary Fund) (2012), 'Safe Assets: Financial System Cornerstone?', in *Global Financial Stability Report: The Quest for Lasting Stability*, World Economic and Financial Surveys, IMF, Washington DC, pp 81–122.

Kane E (2012), 'The Inevitability of Shadowy Banking', Paper presented at the Federal Reserve Bank of Atlanta 2012 Financial Markets Conference 'The Devil's in the Details', Stone Mountain, 9–11 April.

McCabe PE (2011), 'An A-/B-Share Capital Buffer Proposal for Money Market Funds', unpublished manuscript, Board of Governors of the Federal Reserve System.

McCabe PE, M Cipriani, M Holscher and A Martin (2012), 'The Minimum Balance at Risk: A Proposal to Mitigate the Systemic Risks Posed by Money Market Funds', Federal Reserve Bank of New York Staff Report No 564.

Pozsar Z and M Singh (2011), 'The Nonbank-Bank Nexus and the Shadow Banking System', IMF Working Paper No WP/11/289.

Ricks M (2011), 'Regulating Money Creation After the Crisis', *Harvard Business Law Review*, 1(1), pp 75–143.

Shin HS (2010), 'Financial Intermediation and the Post-Crisis Financial System', BIS Working Paper No 304.

Singh M (2010), 'Collateral, Netting and Systemic Risk in the OTC Derivatives Market', IMF Working Paper No WP/10/99.

Singh M (2011), 'Velocity of Pledged Collateral: Analysis and Implications', IMF Working Paper No WP/11/256.

Singh M (2012a), 'The (Other) Deleveraging', IMF Working Paper No WP/12/179.

Singh M (2012b), '"Puts" in the Shadow', IMF Working Paper No WP/12/229.

Singh M (2013a), 'The Changing Collateral Space', IMF Working Paper No WP/13/25.

Singh M (2013b), 'Collateral and Monetary Policy', IMF Working Paper No WP/13/186.

Singh M and P Stella (2012), 'Money and Collateral', IMF Working Paper No WP/12/95.

Stella P (2013), 'Orchestrating the Exit', Stellar Consulting LLC – A Research Blog, 31 July. Available at <stellarconsultllc.com/blog/wp-content/uploads/2013/07/Orchestrating-the-Exit.pdf>.

Summe K (2011), 'An Examination of Lehman Brothers' Derivatives Portfolio Post-Bankruptcy and Whether Dodd-Frank Would Have Made Any Difference', Hoover Institution, Stanford University, Working Group on Economic Policy, Resolution Project draft paper.

Tarullo DK (2012), 'Shadow Banking After the Financial Crisis', Keynote address to the Federal Reserve Bank of San Francisco Conference on Asian Banking and Finance 'Challenges in Global Finance: The Role of Asia', San Francisco, 11–12 June.

Tarullo DK (2013), 'Dodd-Frank Implementation', Testimony before the United States Senate Committee on Banking, Housing, and Urban Affairs, Hearing on 'Mitigating Systematic Risk Through Wall Street Reforms', Washington DC, 11 July.

Tucker P (2012), 'Shadow Banking: Thoughts for a Possible Policy Agenda', Speech given at the European Commission High-Level Conference 'Towards a Better Regulation of the Shadow Banking System', Brussels, 27 April.

Discussion

1. Jason Wu*

The paper by Manmohan Singh covers a lot of ground, and lays out a number of very interesting issues about the nature of the shadow banking sector, and the extent to which the activities of banks and non-banks are interrelated. In particular, it points out that, in addition to deposits, a significant share of bank lending is ultimately funded by non-banks. This funding can be described as 'indirect' deposits managed by 'asset managers'. Banks and non-banks are also linked through the process of collateral intermediation, which is a major form of shadow banking activity.

The paper highlights the importance of collateral for the financial system, and its money-like properties. The analogy between collateral and money is drawn out by comparing the haircut in a collateralised transaction to a reserve ratio, and the amount of rehypothecation of collateral to the money multiplier. The paper shows that the 'velocity' of collateral, defined as the value of collateral transactions divided by the stock of collateral, has decreased by one-third since 2007. The paper goes on to suggest that one way of satisfying the increasing demand for high-quality collateral could be to increase collateral velocity rather than expand the issuance of collateral assets by either the private sector or the government.

The paper draws out the significant role played by central banks in the collateral market by focusing on the example of the United States, where collateralised lending through repo markets is important. In particular, it demonstrates the impact that the payment of interest on excess reserves (IOER) has had on repo rates, and makes the point that quantitative easing (QE) has largely removed good collateral from the market. This has pushed repo rates down. Presumably, the 'unwinding' of QE should lead to an increase in rates, although the net effect of unwinding on the economy will depend on whether unwinding involves central banks giving up 'possession' of collateral or giving up 'ownership'.

The paper considers potential issues for policymakers arising from the collateral intermediation process. On the fiscal side, the paper highlights that the interconnections between banks and institutions in the shadow banking sector that engage in collateral intermediation (e.g. hedge funds, money market funds, agents in derivatives and tri-party markets) raise potential concerns for taxpayers, despite the fact that they do not have an official backstop and are now more subject to regulations. Collateral intermediation also has a number of macroeconomic implications that are of potential concern to policymakers, including the highly procyclical behaviour of collateral values and haircuts, and the interaction between collateral markets and the implementation of monetary policy.

Finally, the paper asks how changes to financial regulations are likely to affect shadow banking activity and collateral markets. In particular, it asks whether changes to regulations around

* The views expressed here are those of the author and do not necessarily represent those of the Federal Reserve System or its staff.

short-term wholesale funding are likely to push collateral intermediation even further into the shadow banking world, and whether an increase in demand for liquid assets driven by regulatory initiatives such as the Liquidity Coverage Ratio (LCR) are likely to increase the prevalence of 'collateral transformation' type services.

I have a number of suggestions for improving the paper, and a few questions.

First, I would suggest that the title of paper should match the content of the paper. Perhaps the most satisfying way of doing this would be to have a discussion that includes some other aspects of shadow banking. For example, Pozsar *et al* (2012) focuses on a number of other important aspects of shadow banking, including particular institutions and instruments such as conduits, special investment vehicles (SIVs), and asset-backed commercial paper (ABCP), as well as other forms of maturity and liquidity transformation. Alternatively, the paper could stay focused on collateral intermediation, but the title could be changed to reflect this.

My second suggestion is that it would be good to see the benefits of collateralised borrowing laid out against the costs. One of the central points of the paper is that if we view collateral as a form of money, the circulation of collateral benefits the economy. However, others have suggested that the reliance of levered institutions on the collateralised lending market and the procyclicality of haircuts amplified the financial crisis (see, for example, Duffie (2010)).

More generally, the paper could benefit from some streamlining, while maintaining many of its key points, perhaps in the following three-part format.

Part 1 could be a quantitative and qualitative discussion of the costs and benefits of collateral intermediation, and potential cost mitigants. For example, the quantitative discussion could consider whether the equation $\Sigma_i y_i = \Sigma_i e_i z_i (\lambda_i - 1) + \Sigma_i e_i$ can be used in a 'mean-variance' way to provide insights into the costs and benefits. The qualitative discussion could be captured in a table of the form:

Benefits	Costs	Cost mitigants
More credit in the real economy – more productive projects	Procyclical nature of collateral leads to financial instability	Limit the exposure of individual entities, particularly systemically important financial institutions
Monetary policy transmission becomes more effective (?)	Counterparty risk becomes more complex as chains get longer (?)	Strengthen rehypothecation rules; alter 'Master repo agreements'
More complete financial markets (?)	Activity drawn outside of regulated entities (?)	Impose regulation on these entities (e.g. floating net asset values for money market mutual funds)
Flatter yield curve, counters froth in financial markets	Encourages the creation of more complex or opaque assets, e.g. securitisation tranches	Limit collateral types that can be used in certain transactions

It would also be useful for the paper to elaborate on or compare the types of collateral intermediation in these terms. For instance, is tri-party repo less desirable than bilateral repo from a financial stability standpoint, given concentration risks (e.g. clearing banks pulling intraday funding from Lehman Brothers)?

If the benefits from Part 1 are sufficiently large, Part 2 could discuss how the supply of collateral might be increased – either by expanding the volume of collateral assets that are available to private markets or by increasing the 'velocity' or re-use of collateral – in a world where central banks have absorbed large amounts of collateral. Relevant issues include:

- the types of central bank facilities that could be effective (e.g. reverse repos or securities lending)
- the extent to which exchanging good collateral for excess reserves is central to achieve the intended real economy goals of QE. I think this point should be made to balance the argument.

Part 3 could then discuss the implications, and intended and unintended consequences for collateral intermediation, of proposed regulations such as limits on banks' short-term funding. Questions of particular interest include whether under-regulated entities will play a bigger role, and the extent to which collateral transformation/optimisation services will take place. Some empirical evidence on these two questions would be great.

References

Duffie D (2010), 'The Failure Mechanics of Dealer Banks', *The Journal of Economic Perspectives*, 24(1), pp 51–72.

Pozsar Z, T Adrian, A Ashcraft and H Boesky (2012), 'Shadow Banking', Federal Reserve Bank of New York Staff Report No 458.

2. General Discussion

Much of the discussion of Manmohan Singh's paper focused on the normative implications of the reduction in collateral in the global financial system from pre-crisis levels. One participant asked about the extent to which the reduction in collateral velocity was a correction from excessive levels, suggesting that the financial crisis had led to the removal of risky, short-term capital from the system. Since such short-term capital could have negative implications for macroeconomic stability, this development could be positive. Other participants noted that there was a trade-off between efficiency and stability in any normative analysis of the reduction in collateral velocity. It was noted that since differing regulatory institutions faced competing objectives, there was an inherent difficulty in ascertaining a jointly optimal velocity of collateral. This led to comments around the importance of choosing which regulators were responsible for identifying excessive velocity, and the range of policy mechanisms that they could use to control this variable. Dr Singh responded to this discussion by commenting that in his view, the shortage of collateral was not only due to a reduction in collateral velocity since the financial crisis from three to two, but also due to a reduction in the size of the collateral base.

One participant argued that the characteristics of collateral remaining in the financial system reflected the effects of the financial crisis, and noted that collateral had exhibited procyclicality, rapid growth, and a general lack of transparency. Another participant expanded on this line of discussion by suggesting that the financial crisis had demonstrated that banks were excessively reliant on short-term unsecured liquidity, and asked how far the financial system should move towards more collateralised funding. Dr Singh indicated general agreement with this view, and suggested higher interest rates on retail savings as a measure that would increase the stickiness and stability of funding to banks. In response to the discussant's comments, Dr Singh also emphasised that his paper was focused on future trends in shadow banking markets, rather than on those that existed in the run-up to the crisis.

Some participants disputed the argument that there was an aggregate shortage of collateral within the financial system. Specifically, they noted that both demand and supply should be responsive to price, and that this endogeneity made claims of a collateral shortage difficult to verify. More generally, they noted that the inability to identify any robustly exogenous factors made causal analysis difficult. Another participant suggested that the accumulation of public sector safe assets by central banks as a by-product of quantitative easing had in effect 'locked' this collateral away from being used by private sector banks, and had therefore contributed to any potential shortage of collateral. These comments led another participant to ask if the fall in high-quality collateral was necessarily bad, given that the initial large liquidity shock had been offset by an injection of central bank reserves. Another participant responded that while short-term liquidity provision was widely supported, it would be undesirable for central banks to replace the private sector as the provider of collateral in a new steady state.

OTC Derivatives Reform: Netting and Networks

Alexandra Heath, Gerard Kelly and Mark Manning*

1. Introduction

In the wake of the global financial crisis, member jurisdictions of the G20 have embarked upon an ambitious program of reforms to the structure and operation of financial markets. One key element of the reform program is to improve the management of counterparty risk and reduce interconnectedness in over-the-counter (OTC) derivative markets by encouraging greater use of centralised financial market infrastructure (Duffie, Li and Lubke 2010) and increasing the collateralisation of counterparty credit exposure. In accordance with the G20 commitments, new legislation was passed in Australia in December 2012, giving the Government the power to impose mandatory central clearing, trade reporting or platform-based execution requirements, if it is deemed necessary.

In promoting central clearing, policymakers aim to secure a number of benefits, including a reduction in exposure through multilateral netting and lower risk of contagion by decreasing interconnectedness between financial institutions. As the policy debate has progressed, however, a number of observers have identified important implementation challenges which, under certain conditions, could undermine the effectiveness of the reform proposals. As Pirrong (2012) argues, 'although [the rules] may reduce some risks, they will simply relocate others, while creating some new ones'.

One concern that features prominently is that the ability of multilateral netting to materially reduce counterparty exposure will depend on the profile of market participants' trading activities and the degree of fragmentation in centralised clearing venues. If the benefits of existing cross-product netting are high and potentially offsetting exposures have to be cleared via different clearing venues, exposures of individual institutions and the system as a whole could actually increase in some circumstances (Duffie and Zhu 2011).

The effectiveness of netting and the size of outstanding net exposures will also have implications for the demand for high-quality liquid assets (HQLA). The transition to central clearing and the implementation of initial margin requirements where derivative trades remain non-centrally cleared will substantially increase the overall system demand for collateral-eligible assets, which may affect pricing, market structure and broader market functioning. Indeed, to the extent that the need to obtain collateral encourages the intermediation of HQLA between those with an excess and those with a shortfall (so-called, collateral transformation), new interconnections between financial institutions may emerge that could affect the resilience of the financial system in adverse conditions.

* The views expressed are the authors and do not necessarily reflect those of the Reserve Bank of Australia.

This paper presents a framework within which to consider these issues, building on the approaches in Jackson and Manning (2007), Duffie and Zhu (2011), and Cox, Garvin and Kelly (2013). The aim is to gain a better understanding of how different characteristics of agents, OTC derivative products and clearing arrangements may affect net exposures, collateral demand and financial stability, so as to identify where additional policy action may be necessary to ensure that the objectives of reforms are realised.

The paper extends previous work in this area in four important respects:

- it extends the 'network' by considering not only the derivative activities of dealers, but also those of agents in the periphery, which we term 'investors';
- it considers the implications of netting and market structure for both counterparty exposure and collateral requirements;
- in a stylised setting, it models the dynamic interaction between derivative exposure and other balance sheet items under alternative clearing arrangements, focusing on how price shocks are transmitted to balance sheets, and how these may trigger liquidity shortages and, *in extremis*, defaults; and
- it examines the potential impact of increased interconnectedness arising from investors acquiring collateral-eligible assets from dealer banks through collateral transformation arrangements, mapping out the dependencies and vulnerabilities associated with these arrangements.

The paper is structured, as follows. Section 2 provides some background on the policy rationale for an expansion in the scope of central clearing and on the implementation challenges that have been identified. Section 3 introduces the basic model framework, which focuses on the netting benefits in terms of exposure and demand for collateral under different clearing arrangements. The results of this section show that the netting benefits of moving from bilateral to central clearing arrangements disproportionately accrue to the 'dealer' institutions in the 'core' because they have a large number of counterparties and relatively balanced portfolios. This result is consistent with the existing literature. In contrast, investors in the periphery of the network have fewer counterparties and, under certain conditions, may have larger net exposure in a centrally cleared environment. Our results suggest that the case for central clearing is strongest for core institutions participating in large OTC derivative markets; the case for institutions in the periphery, which includes investors and smaller financial institutions, will depend on a range of factors.

Section 4 extends the basic model presented in Section 3 by considering the stability consequences of different clearing arrangements. To do this, we allow participants to obtain the collateral required to support their derivative activity by exchanging illiquid assets on their balance sheet. This analysis shows that there are trade-offs when risk is increasingly managed through collateralisation. On the one hand, financial stability improves due to a lower probability of insolvency arising from counterparty default when collateral coverage is higher. On the other hand, increased collateralisation leads to more encumbrance, so the risk of contagion rises because balance sheets are less liquid. Again, most of the financial stability benefits are likely to come from increasing the use of central clearing and collateralisation in the core and extending such requirements to peripheral institutions may, in some circumstances, have stability costs. We also show that potential stability costs arising from illiquidity increase if institutions in the periphery only have indirect access to HQLA via collateral transformation arrangements with the core. In light of the findings of this analysis, Section 5 considers the policy implications, and Section 6 concludes.

2. Background

At the Pittsburgh Summit, in September 2009, the G20 Leaders stated that: 'All standardized OTC derivative contracts should be traded on exchanges or electronic platforms, where appropriate, and cleared through central counterparties by end-2012 at the latest' (G20 2009, p 9). One of the core objectives of this decision is to mitigate systemic risk. This has been interpreted by the Financial Stability Board (FSB) to mean limiting the scope for contagion arising from interconnections between OTC derivative counterparties and the potential for crystallised losses to trigger procyclical increases in collateral calls on counterparties or the large-scale unwinding of exposures (FSB 2010).

Central clearing arrangements are expected to achieve this in a number of ways (Cecchetti, Gyntelberg and Hollanders 2009; Manning, Heath and Whitelaw 2010). First, central clearing generally provides greater netting efficiency, thereby minimising exposure. Second, central clearing is expected to reduce interconnections between institutions, thereby improving the robustness of OTC derivative markets to shocks and increasing financial stability. Third, central counterparties (CCPs) promote standardisation and support operational efficiencies in participants' position management and other back-office functions. Finally, CCPs are regulated against high and internationally consistent risk standards (CPSS-IOSCO 2012), and are able to manage defaults more effectively than bilateral counterparties.

Recognising that some products are not amenable to central clearing, perhaps because they are insufficiently standardised, policymakers have also developed new international principles for counterparty risk management where OTC derivative trades continue to be cleared on a bilateral basis (BCBS-IOSCO 2013). These principles propose harmonised requirements for both initial and variation margin between bilateral counterparties with the aim of replicating the risk management benefits of central clearing, and providing sufficient incentive to submit trades for central clearing wherever it is feasible to do so.

The rest of this section provides background on some of the matters relevant to the question of whether central clearing – and increased collateralisation where trades remain bilaterally cleared – is likely to be effective in achieving the G20's objective.

2.1 Netting efficiency – exposures

Contractual agreements between bilateral counterparties typically allow for bilateral netting of exposures across multiple products. In the event of a counterparty default, outstanding derivative contracts in all products covered by a given bilateral agreement would be terminated and netted against each other, either at agreed market values or at values reflecting any loss to the surviving party from replacing the trades (so-called close-out netting). Exposure in this context refers to potential loss in the event that one party defaults before its settlement obligations are met. Such losses arise when the market price of the contract moves adversely between the default event and the surviving counterparty's close-out of its exposure. This is known as replacement cost risk.

Under central clearing, netting occurs not only across all trades in the products accepted by the CCP, but also across all of a given agent's counterparties (multilateral netting). Duffie and Zhu (2011) make the point that whether netting across products or netting across counterparties minimises exposures is an empirical question and the outcome will differ across markets and individual participants. Relative to bilateral clearing, submitting trades to a CCP will be most effective in reducing aggregate exposures where agents have highly offsetting positions spread across a wide range of counterparties (Jackson and Manning 2007). These conditions are most likely to be satisfied for large dealers in OTC derivatives, who typically seek to hedge exposures that they assume through their trades with non-dealer banks, investors and corporates. Where agents trade with only a small number of counterparties, or there is less scope for netting because derivative exposures are positively correlated, multilateral netting will be less effective.

Duffie and Zhu (2011) establish that central clearing will only reduce exposures if both the number of agents and the size of centrally cleared exposures relative to those that remain bilaterally cleared are sufficiently large. Using data on OTC derivative positions across products, sourced from the Bank for International Settlements, the authors demonstrate that the central clearing of credit derivatives alone would be unlikely to satisfy the conditions for a reduction in total counterparty exposure, while interest rate swap positions may be sufficiently large to justify central clearing.

However, regulatory frictions or the privately chosen product scope of individual CCPs may leave participants unable to clear all related products through a single CCP, and hence unable to take full advantage of the scope for netting. For instance, some jurisdictions require that central clearing of domestic currency OTC derivative transactions take place through an onshore CCP, thereby preventing participants from taking advantage of netting opportunities across related products traded in different markets or currencies.[1]

2.2 Netting efficiency – collateral demand

Replacement cost risk is typically managed through the use of variation and initial margin. Variation margin is typically exchanged in cash at least daily to reflect mark-to-market price changes on participants' outstanding positions. Initial margin, on the other hand, is calibrated to cover, with a high probability, potential future exposure (or additional replacement cost losses that may occur) between the last variation margin payment and the close-out or replacement of a defaulting counterparty's trades. While variation margin is often already exchanged under existing bilateral arrangements, initial margin is generally not. New requirements to apply initial margin where trades are not centrally cleared will therefore constitute an important change in market practice (BCBS-IOSCO 2013).

Variation margin is calculated as the net change in the value of derivative positions due to observed price movements, with netting occurring across products and/or counterparties covered by a given bilateral or central clearing arrangement. Accordingly, variation margin is

1 Interoperability between CCPs could, in principle, reduce the costs of un-netting arising from fragmentation in clearing venues (Cox *et al* 2013). However, interoperability is currently observed primarily between CCPs operating in cash equity markets, rather than derivative markets where contracts are longer dated, principal values are higher, and price volatility is often greater. Notwithstanding their support for interoperability in cash equity markets, European regulators and legislators have reserved their position on derivative interoperability, with the European Commission undertaking to assess the case for interoperability in derivative markets by December 2014. It may, therefore, be a considerable time before interoperability can be entertained in OTC derivative markets.

based on net exposures. In contrast, initial margin is calculated on the basis of future expected price movements and potentially offsetting price movements across products may not be fully taken into account. In CCPs, for instance, so-called 'margin offsets' are typically limited to distinct 'families' of products for which an empirically robust and economically justified correlation in price changes can be demonstrated, including in stressed circumstances. Therefore, even where the empirical covariance between price changes across products may imply significant scope for netting of exposures, the scope for collateral savings is likely to be much narrower.

Initial margin is usually paid in the form of HQLA, and so the netting efficiency of different clearing structures has direct implications for the demand for HQLA. There is increasing concern that the OTC derivative market reforms will lead to a significant increase in demand for HQLA as collateral to cover initial margin requirements because transactions covered by bilateral arrangements typically do not currently require initial margin (Heller and Vause (2011); IMF (2012); ISDA (2012); Sidanius and Zikes (2012); BCBS-IOSCO (2013); and Singh (2013), among others). To the extent that central clearing offers an effective way of reducing exposure arising from replacement cost risk, the increase in demand for HQLA may be mitigated. As noted by Tabb (2012), '… [t]he broader the range of open interest, the more opportunities a clearinghouse has to deliver collateral relief …' However, '… for those who take on directional risk, or whose hedges do not fall into the same clearinghouse, the implications of the new collateral regime will be significant, especially if they use both cleared and un-cleared products'.

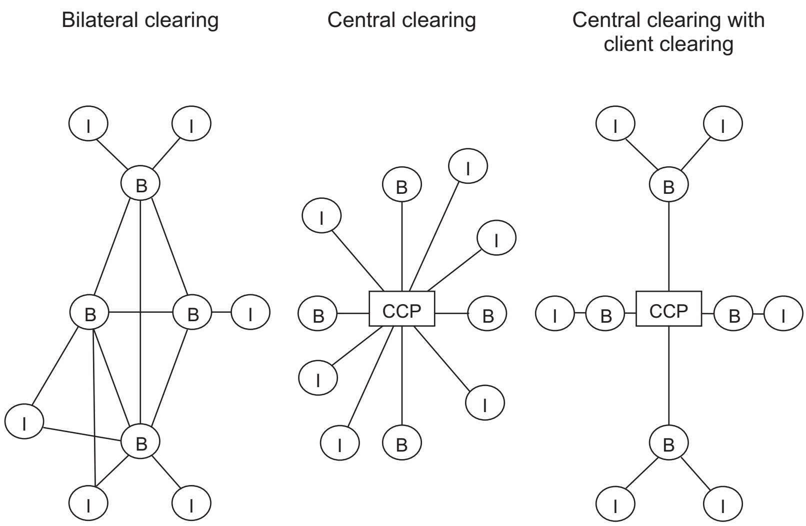
A quantitative impact study carried out by BCBS-IOSCO, summarised in BCBS-IOSCO (2013), estimates that applying initial margin requirements to those positions that do not transition to central clearing could lead to additional collateral demand of between €0.7 and €1.7 trillion, depending on the institutional scope of the requirements. Indeed, this is likely to add to other demands for HQLA arising from impending new liquidity requirements under Basel III and a general trend towards secured funding arrangements (Heath and Manning 2012; CGFS 2013).

The supply of HQLA is likely to be fixed in the short term. Accommodating an increase in collateral demand is therefore likely to involve significant adjustment in markets. This may have implications for the market structure and the network of exposures between financial institutions. For instance, it is likely that increased demand for HQLA will entail widespread portfolio reallocation, both as non-natural holders of HQLA shift a proportion of their balance sheets into such assets, and as existing holders reduce their holdings in response to an adjustment in relative prices. In some cases, including jurisdictions such as Australia with a low supply of HQLA, a policy response may be necessary to smooth the transition (see Heath and Manning (2012), Singh and Stella (2012) and Singh (2013)).

2.3 Network interconnectedness

A CCP becomes the buyer to every seller and the seller to every buyer in the markets it serves, thereby transforming a network of bilateral net exposures between participants into a single set of multilateral net exposures between the CCP and each market participant – a 'star' network (Figure 1). In this way, central clearing aims to reduce direct interconnectedness between counterparties, centralise default management, and address risks of contagion associated with the uncertainty about who is exposed to whom that exists in a bilateral network.

Figure 1: Network Connections under Alternative Clearing Structures



Note: B represents a bank and I represents an investor

2.3.1 Client clearing

The extent to which central clearing simplifies the market structure and reduces the interconnectedness of the network will ultimately reflect the extent to which non-dealer banks, buy-side institutions or other end users of OTC derivatives transition to central clearing and whether they access CCPs as direct participants or indirectly via a clearing agent (client clearing). To the extent that they access central clearing indirectly, a new source of interconnectedness and dependence could emerge within the financial network.

In a client clearing structure, the clearing agent acts as a conduit to the CCP for its clients. The precise nature of the relationship between the client, the clearing agent and the CCP differs across jurisdictions, and across individual CCPs. In the agency model, which is common in the United States, the client maintains a direct contractual relationship with the CCP, but employs the clearing agent to act on its behalf in its day-to-day dealings with the CCP. Outside the United States, including in Australia, the alternative principal model predominates. In this model, the client has no direct contractual relationship with the CCP, only with the clearing agent. Accordingly, the CCP has no recourse to the client in the event of non-performance, and calls upon the clearing agent to guarantee its clients' performance. In either model, new interconnections are established between clearing agents and their clients (Figure 1).[2]

2 The degree of financial exposure between a clearing agent and its clients ultimately depends on whether client positions and collateral are commingled with those of the clearing agent, segregated in an omnibus client account with fellow clients, or individually segregated. It also depends on whether the clearing agent extends credit or provides ancillary services such as collateral transformation.

2.3.2 Collateral transformation

Increasing collateral demand may also increase interconnections in the OTC derivative network if access to HQLA is not evenly distributed. Of particular interest is collateral transformation, whereby an intermediary lends HQLA against less-liquid securities in return for a fee. Collateral transformation is in its infancy, but is widely expected to accelerate as the OTC derivative market reforms are implemented globally (Ellis 2012; ESRB 2012; IMF 2012).

Under such an arrangement, the collateral transformation provider would make HQLA available to an investor to meet a collateral requirement imposed by a central or bilateral counterparty, taking security over less-liquid assets posted by the investor. The clearing agent would either source HQLA from its own inventory or borrow them from another market participant in the repo market, for example. The collateral transformation provider would require that the investor post a higher value of less-liquid assets than the value of HQLA provided (a so-called 'haircut') to protect against a possible adverse change in the value of the less-liquid assets should the investor default.

It is generally acknowledged that, in the face of increasing collateral demands, there are efficiencies to be gained from the emergence of collateral transformation services. These services allow those with a shortfall of HQLA to meet their collateral requirements as they arise, rather than having to maintain these assets on their balance sheet. Other things being equal, such reallocation of portfolios would give rise to a steady-state increase in credit spreads and a concomitant decline in credit availability.

It is also recognised, however, that collateral transformation will be a source of new exposures and interconnections, taking the market further from the simple 'star' network that the OTC derivatives reform agenda originally sought to establish. Among the risks that have been highlighted in the policy debate so far, the potential funding risk for those relying on collateral transformation has been emphasised. In particular, collateral transformation transactions are typically of shorter maturity than the underlying OTC derivative transactions that they support. This introduces a rollover risk, which could crystallise in a number of ways: for example, an idiosyncratic shock to the collateral transformation provider; a tightening of conditions in the wider securities market; or a sharp decline in the value of the less-liquid assets posted as collateral.[3] The underlying market conditions and the responses of both the collateral transformation provider and the customer in such circumstances will determine the extent to which stress is spread more widely through the network.[4]

3 Consider the case of an asset price shock. The collateral transformation provider may respond in several ways: a mark-to-market call for additional collateral; an increase in haircuts; a narrowing of the range of less-liquid assets it is willing to accept as security for its loan of HQLA; or a cessation of its collateral transformation service. Each response could trigger some funding stress for the customer, with potentially procyclical implications for the broader network. If the collateral transformation provider responded by altering its own collateral-acceptability criteria or withdrawing its service entirely, the customer would be forced either to liquidate its derivative positions, or alternatively liquidate some of its less-liquid assets, most likely at fire-sale prices, in order to raise the HQLA it needed to continue to support these positions.

4 The potential for stress to feed back to CCPs in such circumstances has also been recognised. As observed by IMF (2012, p 120), 'large banks that are also clearing members may offer collateral transformation services to their customers to turn less liquid assets into CCP-acceptable ones through repos and swaps. This could potentially exacerbate liquidity pressures for CCPs during market downturns, when clearing members would need to provide liquid funds for their clients at a time when they themselves are being subjected to a liquidity freeze'.

3. Netting under Alternative Clearing Structures

To characterise the way in which alternative clearing structures affect market participants' exposures to each other and their collateral implications, we use a relatively straightforward model that extends the Duffie and Zhu (2011) framework in two dimensions.

First, rather than assume that all participants are equal in size and trade with all the other participants in the market, which is consistent with the description of the core of an interbank or interdealer market, we add a layer of participants that trade with core institutions, but do not trade with each other. Several studies, including Upper and Worms (2004), Bech and Atalay (2010), Craig and von Peter (2010), and Markose (2012), have shown that this 'core-periphery' set-up is a more realistic and complete description of interbank and derivative markets. Babus (2011) shows that when collateral is costly and there are information frictions, a core of intermediary institutions can endogenously form to facilitate more efficient uncollateralised trading within long-term counterparty relationships.

The core of OTC derivative markets is arguably made of up of around 16 global banks that conduct most of their business in large financial centres such as London and New York, but also connect to more peripheral financial institutions that operate in regional financial centres. Since a large proportion of peripheral institutions' OTC derivative transactions are designed to hedge concentrated interest rate and currency risk, they are often highly directional and the logical counterparties to these transactions are large global banks. Extending the framework to include peripheral institutions allows us to consider the implications of different clearing arrangements for market participants such as end users of OTC derivatives and smaller, more domestically oriented investors and banks.

Second, we focus on the collateral implications of different market structures, rather than only the net exposures. This is important because the aggregate demand for HQLA to be posted as collateral to meet initial margin requirements may not have a linear relationship with those exposures. In particular, while variation margin payments reflect the impact of the single net price change on a portfolio of positions across all products held with a bilateral counterparty or CCP, initial margin requirements are typically calculated independently by product class, with only limited scope for cross-product offsets (see Section 2.2). As a result, the demand for HQLA to meet initial margin requirements will be quantitatively much more important than the demand arising from variation margin payments. Another consideration is that demand for collateral to meet initial margin is calculated at the beginning of a transaction and must be available in the event of a default, for example in a segregated trustee account. This reduces the velocity of collateral and increases the amount of collateral required to support a given level of activity.[5] In contrast, once variation margin is paid, typically in cash, the receiver is free to reuse the funds.

3.1 The model

The key elements of the basic model used in this section are the agents, the derivative products and the clearing arrangements. Our model is highly stylised and in the baseline case we do not attempt to calibrate the parameter values to match attributes of the real world accurately. In

5 For a more detailed discussion of the concept of collateral velocity and its potential importance in understanding the evolution of the shadow banking sector, see Singh (2011).

Section 3.4, however, we examine the sensitivity of our results to the choice of parameter values. The model is developed further in Section 4 to examine the dynamic response of the network to price shocks and highlight potential channels for contagion and financial instability.

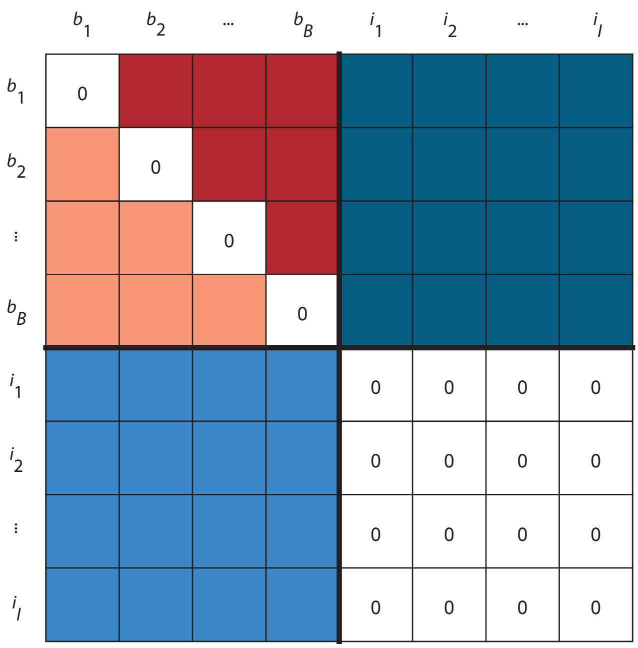
3.1.1 Agents

We assume that the financial system has B banks that make up the core and I investors that make up the periphery. The banks in the core may be thought of as large dealers, while the investors in the periphery may be thought of as buy-side institutions. In the baseline case, we assume that $B = 10$ and $I = 30$.

3.1.2 Derivative products and positions

The net position between agent i and agent j in product d is denoted W_{ij}^{d}. A positive value indicates that i has a 'long' position with j in asset class d, while a negative value indicates a 'short' position. Accordingly, $W_{ii}^{d} = 0$ and $W_{ij}^{d} = -W_{ji}^{d}$. All transactions are contracted on a bilateral basis. The core is characterised as a dense network of banks that trade with all the other banks in the core (the red block in the transaction matrix in Figure 2). Investors transact only with banks (the blue block) and not with each other.

Figure 2: Transaction Matrix



In the baseline case, we assume that there are two classes of derivative product, and that net derivative positions, W_{ij}^{d}, are independent across *i* and *j* and across products. Derivative positions W_{ij}^{d} are randomly assigned according to one of two bivariate normal distributions: N(0, Ω_{PB}) for positions between banks; and N(0, Ω_{PI}) for positions between banks and investors.

We define x_d as the share of a bank's positions in product *d* with other banks, and n_d as the total notional value of each bank's positions in product *d*. In the baseline case, the expected total notional outstanding held by each bank in each of the two derivatives products is normalised at 1. This implies that $n_d = E\left[\Sigma_j \left|W_{ij}^{d}\right|\right] = 1$ and that $n_1 = n_2 = 1$. We also assume that half of these positions are held against other banks and half against investors, that is $x_1 = x_2 = 0.5$. These assumptions pin down the variance-covariance matrix of positions as:

$$\Omega_{PB} = \begin{pmatrix} \left(\dfrac{n_1 x_1}{(B-1)\sqrt{2/\pi}}\right)^2 & 0 \\ 0 & \left(\dfrac{n_2 x_2}{(B-1)\sqrt{2/\pi}}\right)^2 \end{pmatrix} \qquad \Omega_{PI} = \begin{pmatrix} \left(\dfrac{n_1 (1-x_1)}{I\sqrt{2/\pi}}\right)^2 & 0 \\ 0 & \left(\dfrac{n_2 (1-x_2)}{I\sqrt{2/\pi}}\right)^2 \end{pmatrix}.$$

The matrix Ω_R represents the covariance matrix for price movements (or returns) in the two derivative products. In the baseline case, we assume that there is no covariance between price movements (but relax this assumption in Section 3.4.2):

$$\Omega_R = \begin{pmatrix} 0.1^2 & 0 \\ 0 & 0.1^2 \end{pmatrix}.$$

3.1.3 Clearing arrangements

We examine exposures and collateral demands under four alternative clearing arrangements, where:

- both products are bilaterally cleared ('bilateral')
- the core centrally clears both products with a single CCP, while the periphery bilaterally clears both products ('split clearing')
- one product is bilaterally cleared and one product is centrally cleared ('mixed clearing')
- both products are centrally cleared with:
  - each product cleared via a different CCP ('separate CCPs')
  - a single CCP ('single CCP').

Under the centrally cleared arrangements, each bank and investor is assumed to access the CCP directly. We relax this assumption in Section 4.3, where we examine interdependencies introduced by client clearing and collateral transformation.

3.2 Exposures

We start by comparing the exposures generated under each clearing arrangement. Following Duffie and Zhu (2011), exposure is defined as expected loss given default, calculated in terms of the expected change in mark-to-market valuations. This is also the variation margin payment that would have been received had the counterparty not defaulted. If we define ΔP^d as the change in the price of product *d*, then the variation margin payment owing in respect of product *d* is given by $V_{ij}^d = W_{ij}^d \Delta P^d$. $V_{ij}^d > 0$ denotes that *i* receives a variation margin payment from *j*, while $V_{ij}^d < 0$ denotes that *i* pays variation margin to *j*.

Given a transaction matrix and the covariance matrix of price movements for each derivative product, exposures for each agent will differ across clearing structures according to the netting properties of the structure. In particular:

- When both products are bilaterally cleared, exposures are netted across products, between each pair of counterparties. Note that the transaction matrix described in Figure 2 is defined in terms of net bilateral positions, so there is no scope for further netting of individual transactions in a given product executed between a given pair of agents. Under these circumstances, the exposure of agent *i* is given by: $\phi_i = \Sigma_j E\left[\max\left(\Sigma_d V_{ij}^d, 0\right)\right]$.
- When the core is centrally cleared and the periphery is bilaterally cleared, the exposures of these two groups are given, respectively, by: $\phi_{Bi} = E\left[\max\left(\Sigma_d \Sigma_{j\in B} V_{ij}^d, 0\right)\right] + \Sigma_{j\in I} E\left[\max\left(\Sigma_d V_{ij}^d, 0\right)\right]$ and $\phi_{Ii} = \Sigma_{j\in B} E\left[\max\left(\Sigma_d V_{ij}^d, 0\right)\right]$.
- When one product, *d1*, is bilaterally cleared and the other, *d2*, is centrally cleared, exposures in the centrally cleared product are subject to multilateral netting across all participants in the CCP, while exposures in the bilaterally cleared product are bilaterally netted between each pair of counterparties. Under this hybrid model, the exposure of agent *i* is given by $\phi_i = \Sigma_j E\left[\max\left(V_{ij}^{d1}, 0\right)\right] + E\left[\max\left(\Sigma_j V_{ij}^{d2}, 0\right)\right]$.
- When the two products are centrally cleared by separate CCPs, exposures in each product are multilaterally netted across all participants of each CCP separately. The exposure of agent *i* is then given by: $\phi_i = \Sigma_d E\left[\max\left(\Sigma_j V_{ij}^d, 0\right)\right]$.
- When both products are centrally cleared by a single CCP, exposures are netted multilaterally across all products and all participants of the CCP. Under these circumstances, the exposure of agent *i* is given by: $\phi_i = E\left[\max\left(\Sigma_d \Sigma_j V_{ij}^d, 0\right)\right]$.

Table 1 presents exposure metrics for the baseline model under each clearing structure based on a Monte Carlo simulation with 300 000 iterations. The table separately identifies exposures for each class of agent, including CCPs. In the final column, agents' and the central counterparties' exposures are summed to give total system exposure.

Table 1: Baseline Model – Total Exposures
The combined exposure of each agent type

Clearing arrangement	Banks	Investors	All agents	CCPs	System exposure
Bilateral	0.63	0.31	0.94	na	0.94
Split clearing	0.44	0.31	0.73	0.13	0.89
Mixed clearing	0.47	0.26	0.73	0.14	0.87
Separate CCPs	0.15	0.13	0.28	0.28	0.56
Single CCP	0.12	0.10	0.22	0.22	0.44

The differences in the scope for netting give rise to differences in exposure outcomes across clearing structures in the baseline model. Consistent with Duffie and Zhu (2011), a single CCP offers the most netting-efficient solution. The system exposure with a single CCP clearing both products is less than half that in the bilateral structure. If only one product migrates to central clearing, however, the reduction in exposure relative to the pure bilateral structure is relatively limited. This reflects that, while agents can take advantage of multilateral netting for one of the products, the scope to net across products is lost.

The calculations in Table 1 assume there is a zero correlation between prices of the two derivative products. As we show in Section 3.4.2, the higher the (absolute) price correlation across products, the more valuable cross-product netting becomes and therefore the reduction in exposures from migrating one product to central clearing becomes smaller. This again accords with the conclusion in Duffie and Zhu (2011) that centrally clearing just one product may increase exposures. Also, a higher correlation in prices will increase the difference between system-wide exposures under a single CCP and separate CCPs.

Although the size of aggregate exposure falls moving from bilateral arrangements to a single CCP, the distribution of exposures shifts from being largely borne by banks in the core of the system to the CCP. This is consistent with the objective of the regulatory changes, which is to reduce risk in the system by reducing exposures and shifting risk to institutions that are considered to be in a better position to manage the risk; in this case, CCPs. However, the table also shows that, due to the greater scope for multilateral netting, banks in the core of the network benefit disproportionately relative to the investors in the periphery.

The split clearing structure allows us to examine further the relative importance of collateralisation and central clearing for core and peripheral institutions, and for the system as a whole. The second row of Table 1 reveals that, at least for the baseline case in which half of banks' trades are with investors, moving from bilateral to central clearing of trades within the core alone leads to a material reduction in banks' exposures. Investors' exposures, of course, remain unchanged. Total system exposure in the split clearing case remains significantly higher than when both products are centrally cleared. However, to the extent that interbank exposures are more systemically important – perhaps due to their higher concentration or greater propensity to trigger contagion in the event of a default in stressed circumstances – the 'effective' systemic risk reduction under split clearing may be greater than the expected loss captured by the total system exposure metric would imply.

3.3 Collateral demand

The demand for collateral to cover initial margin payments will be a non-linear function of counterparty exposures and the variances of price movements, which determine margin rates. The margin rate, *m*, is set to achieve a minimum level of coverage of price movements. This calculation may be based on the price distribution of an individual product (product-based margining) or of a portfolio margining.

3.3.1 Product-based margining

Unlike the calculation of variation margin, which is based on outstanding positions and observed price movements across all products covered by the counterparty relationship, initial margin calculations typically allow for only limited netting across products. While some margining methodologies applied by CCPs, such as CME SPAN, allow for some cross-product offsets – known as 'inter-commodity offsets' – these are typically applied only where there is a clear, empirically and theoretically robust correlation between the products in question. Initial margining proposals for non-centrally cleared derivatives equally allow very little scope for cross-product offsets in calculating margin requirements (BCBS-IOSCO 2013).

In the case of product-based margining, we assume that no cross-product offsets are applied, and that target collateral coverage for each agent is 99 per cent of single-tailed price movements for each product, consistent with international standards for CCPs (CPSS-IOSCO 2012). Under bilateral clearing, the collateral required to cover initial margin payments from agent *i* to agent *j* for product *d* is then given by $C_{ij}^{d} = m_d W_{ij}^{d}$.[6] Since, with product-based margining, long and short positions in different products are not netted for the purposes of initial margining, $C_{ij} = \Sigma_d \left|C_{ij}^{d}\right| = C_{ji}$, and the collateral requirement for agent *i* will be $C_i = \Sigma_j C_{ij}$. Similarly, for a CCP, the total amount of collateral required from participant *i* is $C_i = \Sigma_d \left|\Sigma_j C_{ij}^{d}\right|$, which is the same whether there is a single CCP for all products, or a separate CCP for each product.

Table 2 reveals how the application of the product-based margining methodology translates to collateral demand under each clearing structure. Although relative collateral demands in Table 2 are qualitatively consistent with the exposures in Table 1, the relative magnitude of collateral demand under the bilateral structure with product-based margining is striking. This reflects that any observed cross-product netting is ignored for margining purposes. Bilateral clearing is therefore by far the most 'costly' market structure in terms of collateral demand and even centrally clearing only one product can give rise to material collateral savings. Indeed, while Table 1 reveals little difference between investors' exposures in the mixed clearing and split clearing cases, collateral demand is significantly higher in the split clearing case when cross-product netting is not reflected in margin calculations. Note also that since agents derive no benefit from pooling exposures with a single CCP when margin is calculated on a product-by-product basis, there is no difference in collateral demand between the single CCP and separate CCP structures. As before, although all agents experience a decline in their collateral needs, the banks in the core benefit disproportionately.

6 The margin rate, m_d, will be equal to the standard deviation of price movements on product *d*, σ_d, multiplied by 2.33 , the cut-off for the 99th percentile in the standard normal distribution.

Table 2: Baseline Model – Collateral Demands
Product-based margining

Clearing arrangement	Banks	Investors	All agents
Bilateral	5.15	2.58	7.73
Split clearing	3.43	2.58	6.01
Mixed clearing	3.07	1.70	4.76
CCP	0.99	0.82	1.80

3.3.2 Portfolio margining

While full portfolio margining is not typically observed, except within product classes, it is instructive to consider full portfolio margining as a lower bound for collateral demand. Under this methodology, initial margin is based on the potential future exposure on a portfolio of products, rather than on each product individually. In this exercise we assume that the margin rate is calibrated to cover 99 per cent of price movements across the entire portfolio, which is consistent with expectations for portfolio-level variation margin obligations calculated in Section 3.2.

Portfolio margining will only be relevant in cases where both products are cleared bilaterally or are cleared centrally through a single CCP. In the case of bilateral clearing, the collateral required for each agent in a bilateral relationship under portfolio margining is given by $C_{ij} = m_{fij}\Sigma_d \left|W_{ij}^d\right| = C_{ji}$.[7] In the case of central clearing, the collateral required of each participant will be given by $C_i = m_{fi}\Sigma_d \left|\Sigma_j W_{ij}^d\right|$.[8]

In general, portfolio margining materially reduces the amount of collateral required for initial margin (Table 3). The extent of the reduction will be affected by the covariance between the price movements of different asset classes and the weights of each asset class in the portfolio (see Section 3.4.2). A comparison of the collateral demands in Table 3 with those in Table 2 demonstrates that material collateral savings may be achieved if (prudent) cross-product netting is recognised in calibrating margin requirements.

Table 3: Baseline Model – Collateral Demands
Portfolio margining

Clearing arrangement	Banks	Investors	All agents
Bilateral	4.05	2.02	6.07
Split clearing	2.80	2.02	4.81
Single CCP	0.77	0.64	1.41

7 In this case, $m_{fij} = 2.33 \times \sigma_{fij}$, where $\sigma_{fij} = \sqrt{\Sigma_u \Sigma_v \frac{W_{ij}^u W_{ij}^v \Omega_R(u,v)}{\left(\Sigma_d \left|W_{ij}^d\right|\right)^2}}$.

8 In this case, $m_{fi} = 2.33 \times \sigma_{fi}$, where $\sigma_{fi} = \sqrt{\Sigma_u \Sigma_v \frac{\left(\Sigma_j W_{ij}^u\right)\left(\Sigma_j W_{ij}^v\right)\Omega_R(u,v)}{\left(\Sigma_d \left|\Sigma_j W_{ij}^d\right|\right)^2}}$.

3.4 Exposure and collateral demand: comparative static analysis

The results in Tables 1 to 3 are, of course, dependent on the baseline parameters chosen. To explore how exposure and collateral demand under each alternative clearing structure vary with product and agent characteristics, we conduct a number of experiments, individually varying key parameters of the baseline model. In particular we consider the effect on exposure and collateral demand of: varying the size of the core relative to the periphery (Section 3.4.1); varying the characteristics of derivative products (Section 3.4.2); and allowing a sub-section of the periphery to take directional derivative positions (Section 3.4.3).

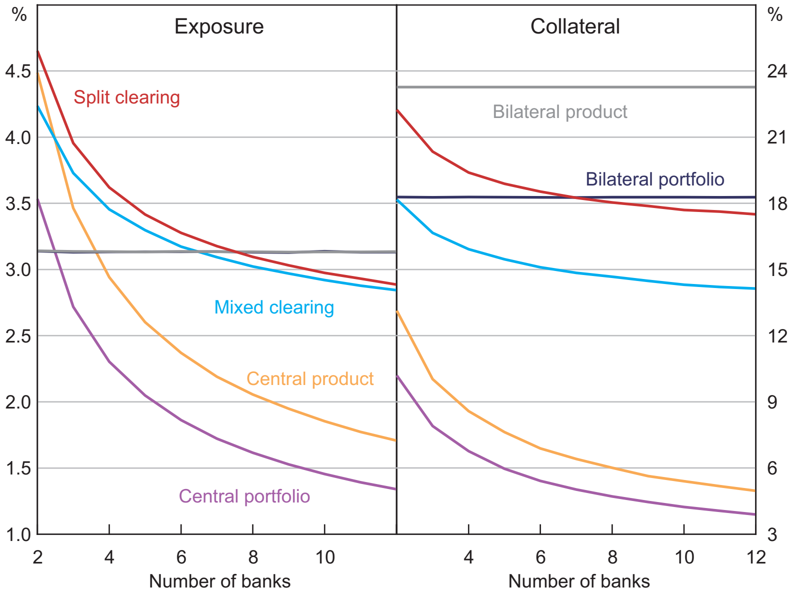
3.4.1 Varying the size of the core relative to the periphery

One of the motivations for extending the Duffie and Zhu (2011) model is to understand how the presence of institutions in the periphery might affect conclusions around the costs and benefits of central clearing arrangements. To do this, we examine the effects on exposure and collateral demand of: varying the size of the core, while keeping the size of the periphery fixed; varying the size of the periphery, while keeping the size of the core fixed; and varying the share of notional amounts outstanding traded within the core.

Figure 3 summarises the effect of linearly increasing the number of banks in the core on total system exposure and total collateral demand relative to total notional outstanding, under each clearing structure, holding the total size of notional amounts outstanding fixed.[9] As expected, when derivatives are bilaterally cleared, varying the number of banks in the core has no effect on either relative exposure or relative collateral demand since, under this clearing structure, there is no scope for netting across counterparties. In contrast, in structures involving central clearing, exposures and collateral demand decline steadily as the number of banks in the core increases, though at a decreasing rate. This is intuitive: multilateral netting across counterparties is more valuable, the larger the number of counterparties (Jackson and Manning 2007). The left-hand panel of Figure 3 shows that for a small core, netting across products available in a bilateral clearing relationship may be more important than netting across counterparties. This is consistent with the findings in Duffie and Zhu (2011). This may also be true for collateral demand (the right-hand panel), depending on whether initial margin requirements are calculated on a product or portfolio basis.

9 It can be shown that outcomes for exposure and collateral relative to total notional outstanding are equivalent whether the number of banks (investors) is varied keeping the total system notional position fixed, or keeping the position size per agent fixed.

Figure 3: Changing the Size of the Core
Exposure and collateral relative to notional outstanding



Notes: Total derivative positions reflect net notional amounts outstanding, drawn from the transaction matrix in Figure 2; the clearing structures are described in Section 3.1; calculations are based on Monte Carlo simulation, with 300 000 iterations; in each panel the number of banks varies; all other parameters remain as in the baseline case: $I = 30$; $n_1 = n_2 = 1$; $x_1 = x_2 = 0.5$; $\sigma_1 = \sigma_2 = 0.1$; $cov(1, 2) = 0$; total expected system exposure (left-hand panel) is calculated as in Section 3.2; total system collateral (right-hand panel) is calibrated to a single-tailed confidence interval of exposure of 99 per cent and calculated for each clearing arrangement as in Sections 3.3.1 and 3.3.2

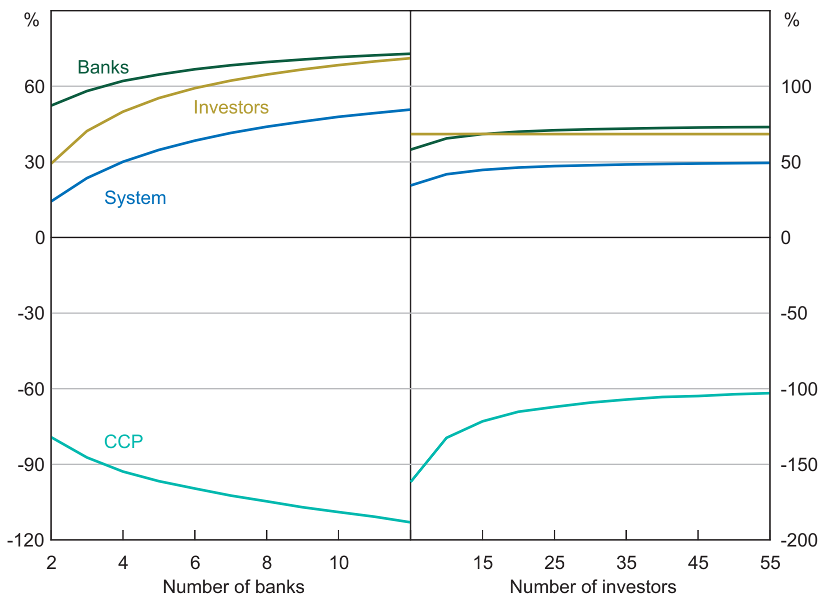
Figure 3 also reveals that, in the case of split clearing (for the baseline case in which half of the nominal value of each bank's trades is with the periphery), exposure falls to below that under full bilateral clearing as the number of banks increases. Further, split clearing always gives rise to higher exposure for these parameter values than the mixed case, though exposure always remains above that under full central clearing.

A similar picture emerges when we consider increasing the number of investors with a fixed number of banks in the core; there is a steady decline in both exposure and collateral demands in the arrangements involving central clearing, as multilateral netting opportunities increase. However, these benefits accrue only to the core (again, since investors do not trade with each other, they experience no change in the scope for multilateral netting of their exposures).

Figure 4 examines the implications of network structure by comparing the relative reduction in exposure for each agent type as central clearing (via a single CCP) is extended to the periphery. In the left-hand panel, changes in exposure are tracked as the number of banks in the core increases, and in the right-hand panel as the number of investors in the periphery increases. It is evident that when there are only few banks in the core, the benefits to investors from central clearing are relatively limited. Again, this reflects relatively less scope for multilateral netting. This is equivalent to investors trading only with a few dealers, which for many investor types is likely to accord with observed practice. As the number of core banks increases, however, the benefits to investors converge on those for banks, since the scope for multilateral netting increases. The right-hand panel, on the other hand, shows that investors' exposures remain unchanged as the number of investors changes (since investors are assumed not to trade with each other). Increasing the number of investors does, however, generate multilateral netting benefits for banks, and therefore there is a material reduction in exposure for the core.

Figure 4: Extending Central Clearing to the Periphery

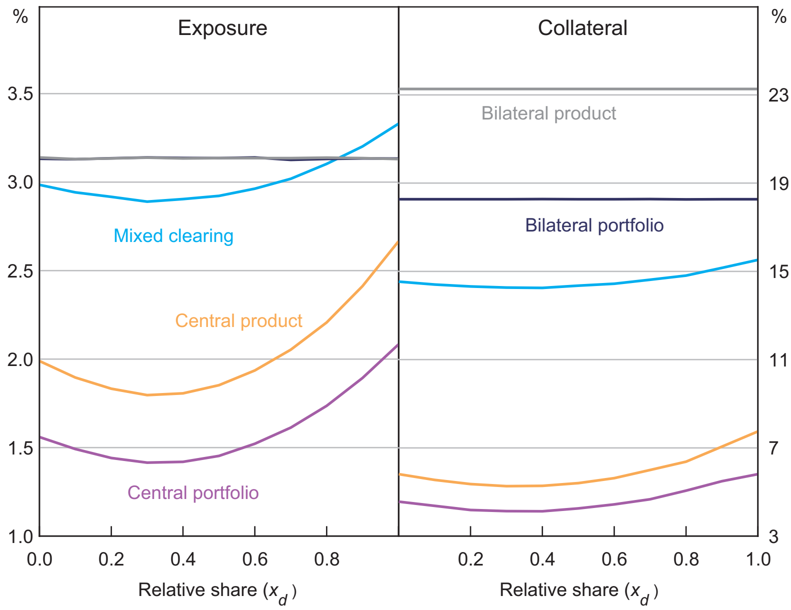
Percentage reduction in expected exposure from extending central clearing to investor positions



Notes: See notes to Figure 3; the figure presents the percentage reduction in expected exposure from all agents clearing centrally via a single CCP, relative to the split clearing structure; in the left-hand panel $I = 30$, in the right-hand panel $B = 10$; all other parameters remain as in the baseline case in Figure 3

Finally, it is also instructive to consider how netting efficiency and collateral demand change when the share of OTC derivative transactions occurring within the core varies (Figure 5). As the degree of concentration of transactions increases within a relatively small core of 10 banks, the relative benefit of central clearing versus bilateral clearing diminishes. This reflects that with a smaller share of exposure outside the core, multilateral netting benefits associated with exposure to the periphery decline.

Figure 5: Changing the Relative Share of Interbank Positions
Exposure and collateral relative to notional outstanding



Notes: See notes to Figure 3; in each panel the share of transactions occurring within the core, x_d, varies; all other parameters remain as in the baseline case in Figure 3

3.4.2 Varying the characteristics of derivative products

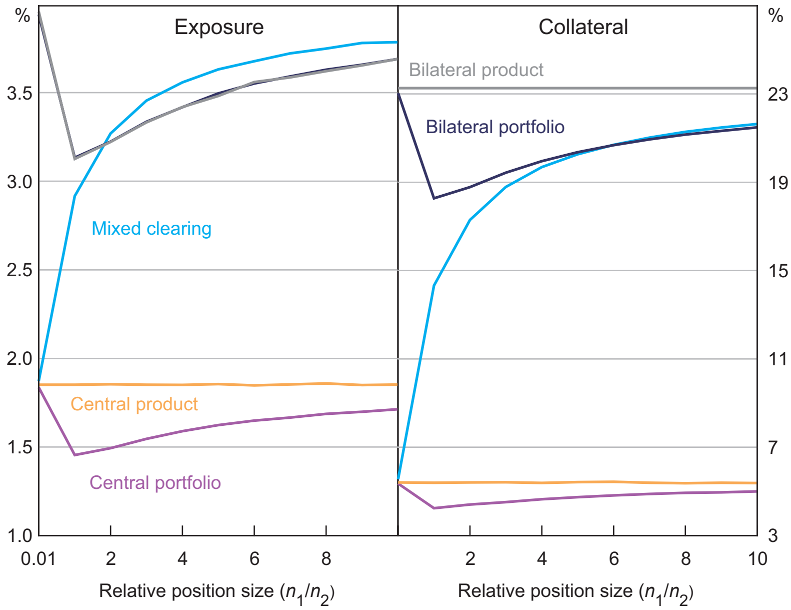
The netting efficiencies of different clearing structures also depend on the characteristics of the derivative products that are traded. To examine this, we vary the relative size of the two derivative products and the relative volatility of their prices, and allow their prices to be correlated. In a final experiment, we also allow the number of products to vary.

In the first experiment, we scale up the size of positions in one derivative product incrementally and consider the implications for total system exposure and collateral demand (relative to total system notional amounts outstanding) across the different clearing arrangements. In the mixed clearing case, we increase the size of the bilaterally cleared derivative. Two observations in Figure 6 are particularly striking:

- First, increasing the relative size of positions in the bilaterally cleared derivative product materially increases both exposure and collateral demand in the mixed clearing structure. This is consistent with Duffie and Zhu (2011). In effect, the multilateral netting benefits from centrally clearing one product diminish as the size of positions in the bilaterally cleared product increase, and the characteristics of the portfolio converge to those under pure bilateral clearing. Indeed, at some point, the 'un-netting' effects result in slightly larger exposure in the mixed clearing case.
- Second, exposure under the single CCP structure gradually approaches that under the structure with separate CCPs. The interpretation of this result is similar: as the size of one

product increases relative to the other, the benefits of netting across products begin to diminish. This also holds for collateral: in the structures with portfolio margining, collateral demand starts to converge on that with product-based margining.

Figure 6: Changing the Relative Size of Derivative Positions
Exposure and collateral relative to notional outstanding



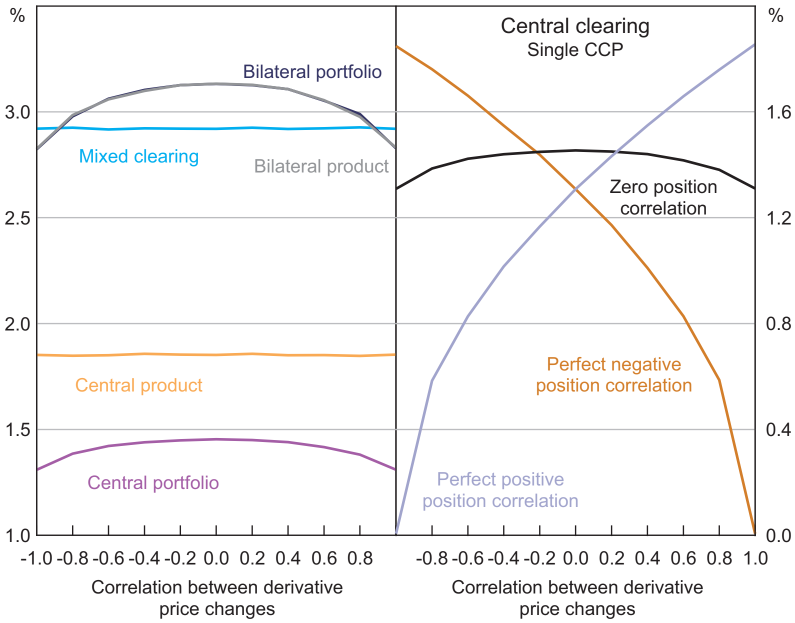
Notes: See notes to Figure 3; in each panel the relative position size in the two products, n_1/n_2, varies; in the mixed clearing scenario, derivative product 1 is bilaterally cleared and product 2 is centrally cleared; all other parameters remain as in the baseline case in Figure 3

In the second set of experiments, we allow the volatility of derivative prices to vary and the correlation between them to be non-zero. As one would expect, increasing the volatility of one derivative product while the other is held fixed leads to an almost linear increase in exposure and collateral demand. The increase in exposure is steeper for the bilateral clearing structures, due to the diminishing scope for any netting as volatility in the price of one product dominates price changes in the portfolio. Similarly, as the benefit of cross-product netting diminishes, collateral demand under product and portfolio margining in each of the bilateral and centrally cleared structures rise at the same linear rate.

As foreshadowed in Section 3.3, allowing the covariance between derivative price changes to be non-zero has significant implications for exposure and collateral demand. In particular, for those clearing arrangements that allow for cross-product netting (i.e. bilateral clearing and clearing via a single CCP, left-hand panel Figure 7), exposure falls when derivative price changes either become more positively or more negatively correlated. A similar hump-shaped profile is also evident for collateral demand when correlations between derivative price changes are taken into account in setting margin requirements.

Figure 7: Changing Correlations between Derivative Prices and Positions

Exposure relative to notional outstanding



Notes: See notes to Figure 3; in both panels the correlation between price changes in the two products varies between –1 and +1; all other parameters remain as in the baseline case in Figure 3

In the baseline model, we have assumed that there is no correlation between participants' positions in the two derivative products. One would expect that as the correlation between these positions increases, the impact of increasing the (absolute) correlation between prices on exposure would also increase. The right-hand panel of Figure 7 illustrates this point for the case of central clearing with a single CCP. As positions become more negatively (positively) correlated, and prices become more positively (negatively) correlated, exposure tends to zero because these combinations constitute fully hedged positions. The highest exposure occurs when prices and positions both have correlations of either +1 or –1.

Finally, we consider the implications of changing the number of derivative products. As might be expected, and consistent with Duffie and Zhu (2011), increasing the number of products increases the value of cross-product netting. Accordingly, as the number of products increases, bilateral clearing and central clearing via a single CCP begin to look proportionally better than fragmented clearing arrangements.

3.4.3 Directionality

In the baseline model, we have assumed that the net positions between institutions in product *d* are independently drawn from a normal distribution with mean zero. In general, this is likely to be a good first approximation for net positions between banks in the core of the network, since these are large global banks that act as intermediaries to the periphery and much of this 'interdealer' activity is intended to distribute risk efficiently throughout the system.

For the periphery, however, it is quite likely that many institutions' OTC derivative positions are designed to hedge exposure arising from other activities. For example, a pension fund may seek to hedge interest rate or currency risk in its investment portfolio; a peripheral bank may seek to hedge the currency risk associated with offshore funding, or the mismatch between the interest rate exposure of its assets and liabilities; and a mining company may use derivatives to hedge its exposure to a change in commodity prices. Furthermore, there may be clusters of institutions in the periphery with very similar net OTC derivative positions, with their natural counterparties often large global banks who subsequently lay off any residual exposure by trading with other banks in the core. In this subsection, we consider how exposure and the demand for collateral change under different clearing arrangements if a subset of financial institutions in the periphery (investors in the terminology of the model) has directional positions.

To do this, we assume that a subset of investors in the periphery draw their positions from a half normal distribution with mean zero. The remaining investors draw their positions from the normal distribution described in Section 3.1. As the directionality of the periphery increases, modelled here as an increase in size of the directional subset, the scope for multilateral netting diminishes. Netting across products may, in such circumstances, be a more important driver of exposure – and hence collateral demand – than netting across counterparties.

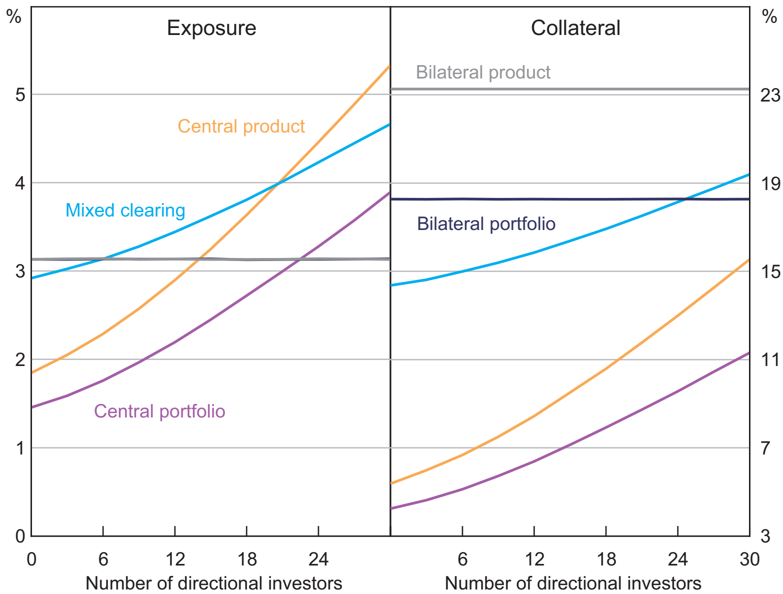
This is confirmed by Figure 8, which reveals that as the directionality of the periphery increases, the benefit of multilateral netting in the structures involving central clearing declines and exposure eventually rises to be above that in the bilateral and mixed clearing structures. This may seem surprising, particularly since central clearing via a single CCP allows netting across both counterparties and products. The increase in centrally cleared exposure above that under bilateral clearing can, however, be explained by the fact that system exposure is the sum of exposures to all agent types, including CCPs; the net exposures of each agent type under central clearing with a single CCP remain below those under bilateral clearing. Since the CCP does not post collateral, higher exposure under central clearing relative to bilateral clearing does not translate to higher collateral demand.

The fact that exposure and collateral demand are independent of the number of directional investors in the bilaterally cleared arrangements is a function of the assumption that there is zero correlation between derivative prices. If the prices of the two derivative products were correlated, there would be greater scope for cross-product netting, especially if the positions were negatively correlated (see Section 3.4.2). Opportunities to net across products would further increase the relative advantage of bilateral over centrally cleared arrangements.

These results highlight the importance of considering the size and distribution of positions in the periphery when analysing the costs and benefits of alternative clearing structures. In some cases, the cross-product netting available under bilateral arrangements may be more valuable than the cross-counterparty netting under central clearing arrangements, and lead to lower exposure. It is also the case that because the core benefits disproportionately from multilateral netting, the costs and benefits of different arrangements may differ across agent types.

Figure 8: Changing the Directionality of the Periphery

Exposure and collateral relative to notional outstanding



Notes: See notes to Figure 3; in each panel the number of directional investors in the periphery varies; directionality is modelled as a draw from a half normal distribution with mean zero; all other parameters remain as in the baseline case in Figure 3

3.5 Summary

The results in this section confirm that central clearing generally delivers lower exposure and collateral demand. However, the magnitude of the benefits from central clearing, and to whom they accrue, will depend on the particular characteristics of agents and the products they trade. In particular:

- Given the more limited multilateral netting benefits available to investors, the exposure reduction associated with central clearing accrues disproportionately to the core. When the notional value of trades executed with the periphery is low relative to that executed within the core, the effective number of core counterparties with which investors typically trade is small. When investors' trades are highly directional, the relative benefits to investors from central clearing are further reduced.
- Netting across products (which is available under bilateral clearing, or clearing via a single CCP) may, in some circumstances, deliver greater benefits than netting across counterparties, particularly when cross-product offsets are taken into account in calibrating initial margin requirements. Such netting will be more valuable the higher are the absolute correlations between positions and/or prices in the two derivative products. In such circumstances, bilateral clearing may appear more favourable than fragmented central clearing or mixed clearing arrangements.

4. Networks under Alternative Clearing Structures

One of the main arguments for moving to central clearing is that it offers netting benefits relative to bilateral clearing. These benefits accrue to individual institutions and, as the analysis in Section 3 has highlighted, they are likely to be higher for institutions in the core of the financial network. Another argument for moving to central clearing is that it will result in a more robust network than one comprising only bilateral arrangements. Recent literature has suggested that in interbank or interdealer financial networks, central clearing is robust to 'random' defaults, but may be fragile in the face of multiple correlated defaults (Gai, Haldane and Kapadia 2011). An alternative characterisation of this is that CCPs lower the risk that isolated (extreme but plausible) defaults have systemic consequences, but concentrate the consequences and management of multiple defaults within one institution. A countervailing benefit of a CCP, however, is that its central position should allow it to manage the liquidation of defaulters' outstanding positions more efficiently than could a network of bilateral counterparties. In this section, we look at the financial stability consequences of different clearing arrangements in our core-periphery model by considering the size and composition of agents' balance sheets, and examining the dynamic behaviour of the network in response to changes in asset prices.

For each institution we specify a balance sheet which comprises only illiquid assets (IA) funded by either debt liabilities or equity. Banks and investors are able to convert IA into HQLA to meet the collateral requirements related to their OTC derivative exposure. We allow IA prices to change relative to those for HQLA and examine how increasing the level of collateralisation under the alternative clearing arrangements affects exposure, collateral demand and vulnerability to default.

In our model, default can occur either because cumulative losses wipe out the equity of a bank (which we term insolvency), or because a bank or investor has insufficient unencumbered assets on its balance sheet to raise the HQLA required for a margin payment (which we term illiquidity). The dynamic nature of the exercise allows us to examine how the default of one institution affects the stability of the financial system as a whole under different clearing arrangements.

After discussing the main results in Section 4.2, we extend the model further in Section 4.3, by assuming that institutions in the periphery rely on institutions in the core to source the HQLA they need to meet their collateral obligations; that is, they rely on collateral transformation. This allows us to isolate a particular source of interconnectedness between the core and the periphery that may generate additional liquidity pressures for individual institutions and become an additional channel for contagion between institutions. In Section 4.4, we look at the sensitivity of the results in the model with collateral transformation to different parameter values. Section 4.5 provides a short summary of the findings.

The model is highly stylised to ensure tractability in the simulation, and the parameters describing agents' activities and balance sheets are not sufficient to replicate the observed complexity of agents' exposures. For instance, given the simple structure of the balance sheets we use, all observed asset encumbrance is attributed to meeting collateral requirements associated with derivative exposure. In a richer setting, with more types of assets and liabilities, OTC derivative positions could be modelled as the marginal source of encumbrance, and accordingly as an amplifier of stress rather than its proximate cause. Furthermore, parameter values in the baseline model exaggerate the economic significance of OTC derivative positions. This enables us to draw out key relationships, dependencies and interactions, and to demonstrate how derivative exposure and the arrangements used to manage counterparty risk may either amplify or mitigate the effect of asset price shocks.

4.1 The model

The dynamic model builds on the static model in three main ways:

- it includes stylised balance sheets that are specified for both banks and investors, allowing OTC derivative exposure and collateral demands to interact with other balance sheet components
- it allows for institutions in the network to default either due to illiquidity or insolvency, resulting in seizure of collateral and, in some circumstances, crystallisation of losses, with possible spill-over effects
- a Monte Carlo simulation is run, with 70 000 iterations, in accordance with a specified time line of events to examine how the system responds to balance sheet shocks under alternative clearing structures.

We assume participants in the network can hold two types of assets on their balance sheets: HQLA and IA. HQLA are held solely to meet market participants' collateral obligations. The price of IA in units of HQLA, P_t^A, varies exogenously from one period to the next according to a random walk, with the percentage change $\Delta p_t^A \sim N\left(0,\sigma_A^2\right)$ and $P_{t+1}^A = P_t^A\left(1+\Delta p_t^A\right)$.[10] It is assumed that the initial price $P_0^A = 1$. In the baseline case, the standard deviation of IA prices is assumed to be $\sigma_A = 0.05$. Initially, both banks and investors are assumed only to have IA on the asset side of their balance sheets.

Assets may be funded by equity, *K*, or (unspecified) debt liabilities, *L*, which have a fixed price (relative to HQLA). Banks start with 5 per cent equity in the baseline model, whereas investors are assumed to be entirely funded by equity (consistent with investors representing buy-side institutions such as pension funds or collective investment schemes). Each period, the price of IA can move. This leads to changes in the value of assets that can only be accommodated by changes in the value of equity, given that, for banks, the value of other liabilities remains constant in HQLA terms, and investors only have equity liabilities. The initial size of banks' balance sheets is assumed to be one-tenth the expected total notional outstanding of their derivative positions (0.2), and twice the size of investors' balance sheets (0.1).

10 The assumption that prices follow a random walk and have constant variance is in contrast to many models that explore the role of collateral in the dynamics of a financial crisis (for example, Kiyotaki and Moore (1997), Brunnermeier and Pedersen (2009) and Anand, Chapman and Gai (2012)). In these models, when liquidity becomes scarce, the price of relatively illiquid assets falls relative to HQLA, which leads to margin calls for transactions where these assets have been used as collateral. This in turn can lead to fire sales and further falls in relative prices and market liquidity, and further contagion. Allowing this transmission mechanism to operate is likely to amplify the dynamics in our model, and this extension is left to further research. Endogenous prices are also important during a transition from one set of clearing arrangements to another. This is not relevant in the current context because we are comparing dynamics under different arrangements, not the transition between clearing arrangements.

Stylised Balance Sheets
Percentage, at $t = 0$

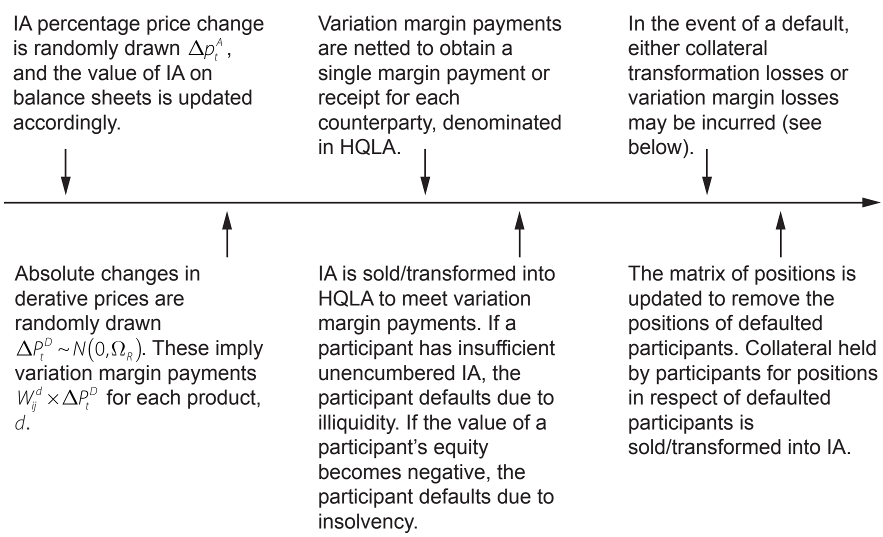
Each bank		Each investor	
Assets	Equity and liabilities	Assets	Equity and liabilities
IA: 100	L: 100–k	IA: 100	K: 100
	K: k		

Derivative positions do not appear on the balance sheet, but once positions are established, HQLA must be acquired to meet associated initial margin requirements. This has consequences for balance sheets. Initially, institutions in the network are assumed to have access to a Securities Market in which IA can be sold to generate HQLA (and vice versa) at the asset price P_t^A. We assume that there are no shortages of HQLA in aggregate (CGFS 2013). The total amount of HQLA required to cover the initial margin on participant i's derivative transactions is the collateral position discussed in Section 3. The HQLA pledged to either a central or bilateral counterparty to meet an initial margin requirement appears as encumbered HQLA on the asset side of the balance sheet, and the remainder of a bank's assets are IA. Derivative positions are marked to market each period, which generates variation margin payments in HQLA. These have further implications for balance sheets in subsequent rounds of the simulation.

In the baseline scenario, we assume that balance sheets are around one-tenth the size of outstanding notional derivative positions. As noted, the combination of parameters chosen in the baseline model aims to highlight the underlying mechanisms more starkly than may be realistic. We go some way towards exploring the implications of our parameter choices in Section 4.3. However, there is scope for further work on this.

At $t = 0$, the transaction matrix is populated as in the model in Section 3.1. In each subsequent period, the following actions are described by the time line in Figure 9.

Figure 9: Time Line



The baseline simulation runs for five periods. The larger the number of time periods, the greater the scope for losses and bank or investor defaults to occur. In particular, any depletion of unencumbered IA, for reasons including variation margin losses incurred or price changes, increases an agent's vulnerability to derivative price shocks in the next period.

Bank or investor defaults may arise in two ways in the model:

- *Insolvency*. Changes in asset prices and the payment or receipt of variation margin can expand or shrink the size of agents' balance sheets. Any change in the asset side of a balance sheet is necessarily balanced by an equivalent change in equity. Should an agent's equity be fully depleted, that agent is considered to have defaulted due to insolvency. Only a bank can become insolvent, however, since investors do not hold any non-equity liabilities.
- *Illiquidity*. To meet a variation margin call, a bank or investor must sell IA to purchase HQLA. This is done in the Securities Market. Should an agent be unable to meet a variation margin call due to insufficient unencumbered IA, that agent is considered to have defaulted due to illiquidity. There are three factors that can lead to a decline in unencumbered IA, and hence potential illiquidity: IA may be sold to generate HQLA to meet initial margin requirements on derivative positions established at $t = 0$; the value of IA may decline due to adverse IA price shocks; and holdings of IA may be depleted due to variation margin payments.

Should a bank or investor default, the surviving counterparty seeks to cover any unpaid variation margin owed using initial margin previously collected from that party. Should this be insufficient to cover the defaulting party's obligation, the shortfall is either subtracted from the surviving counterparty's IA (in the case of bilateral clearing), or subtracted in equal shares from the IA of all surviving participants of the CCP (in the case of central clearing). This is therefore another channel for contagion: changes to IA from 'variation margin losses' may cause other agents' IA or equity to become negative, in which case there would be further defaults, and further losses may arise.[11]

4.2 Collateral coverage and system stability

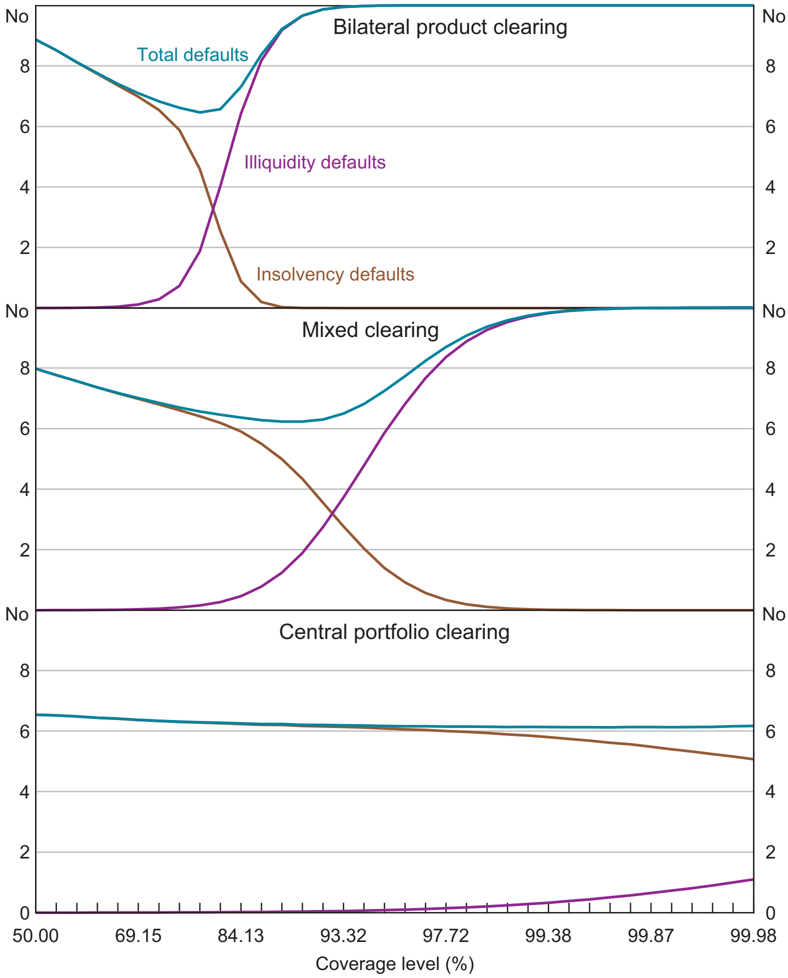
Figure 10 plots the expected number of bank defaults at differing levels of collateral coverage for three of the clearing arrangements under consideration: bilateral clearing with product-based margining, mixed clearing, and central clearing with portfolio margining.[12] Since losses arise in only one tail of the distribution for any agent (e.g. the default of a counterparty with a long position only gives rise to losses if the price has declined), 50 per cent coverage of the price distribution is achieved with zero collateral. The key metric of interest is the expected number of bank defaults.

11 The allocation of unfunded losses in the CCP case reflects the mutualisation principle that characterises CCPs' activities. It simplifies the risk frameworks typically observed, however, in that CCPs generally also have a layer of 'funded' financial resources – a default or guarantee fund – comprising up-front contributions from participants and the CCP itself. In not modelling this layer, our model understates the liquidity cost of central clearing.

12 We focus on just three arrangements to simplify the exposition. Since the chosen arrangements include those that exhibit the greatest (central clearing with portfolio margining) and least (bilateral clearing with product-based margining) netting and collateral efficient arrangements in the baseline model, they cover the broad span of outcomes. Results for the other clearing arrangements are available from the authors, on request.

Figure 10: Insolvency, Illiquidity and Collateral Coverage

Expected number of defaults



Notes: The clearing structures are described in Section 3.1, and the timeline is described in Figure 9; the baseline parameters are $B = 10$; $I = 30$; $n_1 = n_2 = 1$; $x_1 = x_2 = 0.5$; $\sigma_1 = \sigma_2 = 0.1$; $cov(1, 2) = 0$; $\sigma_A = 0.05$; $k = 0.05$; balance sheet size = 0.2 (banks) and 0.1 (investors); calculations are based on Monte Carlo simulation with 70 000 iterations, and five periods

Consistent with its role in mitigating the losses associated with a counterparty default on an OTC derivative contract, increased collateral coverage is associated with a decline in the incidence of bank defaults due to insolvency.[13] This is depicted by the downward-sloping brown line in each plot.

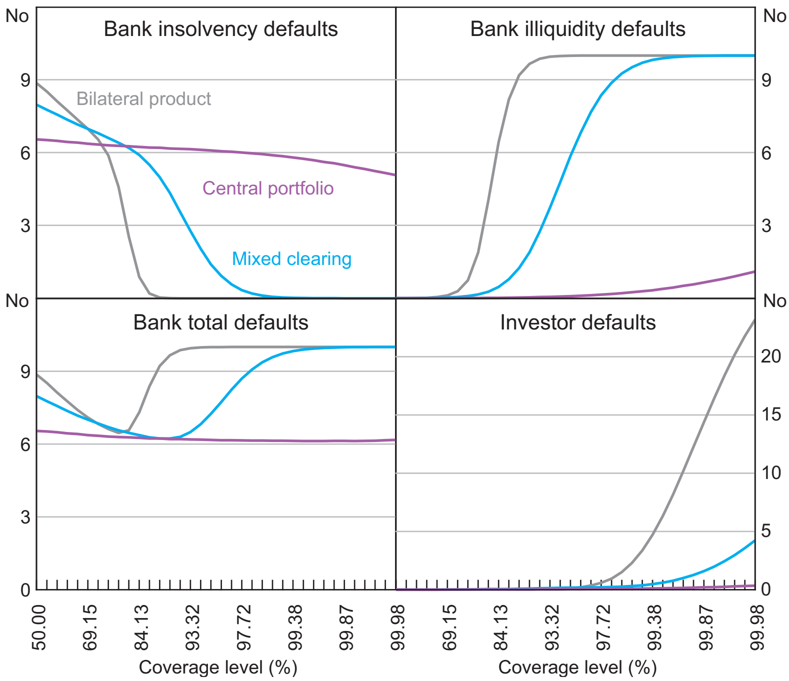
13 Note that in this model banks can only default for one reason. Therefore, if a bank defaults due to illiquidity, it cannot also default due to insolvency. An increase in the incidence of illiquidity therefore contributes to the decrease in the incidence of insolvency, steepening the downward slope of the insolvency line.

However, at the same time, as collateral coverage increases, agents must encumber a larger share of their balance sheets, making them more vulnerable to asset price shocks and reducing their ability to access liquidity to meet future variation margin obligations. This vulnerability is reflected in an increase in the incidence of bank defaults due to illiquidity (the upward-sloping purple line in each plot). There is a level of collateral coverage at which the increase in defaults due to illiquidity exceeds the decrease in defaults due to insolvency, revealing a U-shaped relationship between total expected bank defaults and collateral coverage. That is, there will be an optimal level of collateral coverage which represents the best trade-off between insolvency and illiquidity.

There are notable differences across clearing arrangements in the slopes of the curves and the level of collateral coverage at which total expected bank defaults reaches a minimum. Consider first bilateral clearing with product margining (the first panel of Figure 10). As collateral increases from 50 per cent coverage, the incidence of bank defaults due to illiquidity increases at a faster rate than the decline in bank defaults due to insolvency, and rapidly exceeds the highest level of bank defaults due to insolvency. When central clearing of at least one product is introduced, the gradient of the curves flatten a little, resulting in an extended U-shaped 'total defaults' curve that reaches a minimum at a higher level of collateral coverage. With both products centrally cleared, the increase in bank defaults due to illiquidity and the decline in bank defaults due to insolvency as collateral coverage increases are less pronounced. The 'total defaults' curve does, however, attain a minimum at a very high level of coverage. The key driver of the difference in the slopes is the greater collateral efficiency of central clearing highlighted in Section 3.

Figure 11 summarises the results by separately identifying the source of default – that is, insolvency and illiquidity (top panels) – and plotting expected total bank and total investor defaults (bottom panels). The plot of total bank defaults, in particular, illustrates clearly how greater netting efficiency shifts optimal collateral coverage to the right and flattens the U-shaped relationship between bank defaults and collateral coverage. As noted in Section 4.1, investors cannot default due to insolvency because they are fully funded by equity and can therefore *only* default due to illiquidity. The incidence of investor defaults rises particularly sharply with collateral coverage in the clearing arrangements with low netting efficiency at coverage levels that exceed the optimum, but increases only marginally under central clearing.

Figure 11: Insolvency, Illiquidity and Collateral Coverage
Expected number of defaults



Notes: See notes to Figure 10

4.3 Collateral transformation

Although we continue to assume that there is no shortage of HQLA in aggregate, we now adapt the model described in Section 4.1 to assume that, due to segmentation in markets and other frictions, access to HQLA is not evenly distributed (BCBS 2012). In particular, we assume that banks in the core retain their access to the (un-modelled) Securities Market to obtain HQLA, but that investors can only obtain HQLA by entering into a collateral transformation agreement with a core bank. This creates new interconnections between the core and periphery. This is likely to be an increasingly important feature of funding markets going forward, as described in Section 2.2.4.

We further assume that the bank that provides collateral transformation services to a given investor using central clearing does so in conjunction with client clearing services. In particular, each investor is assumed to access the CCP via a clearing agent, but with an individually segregated client account, such that no financial exposure is created between the investor and its clearing agent other than through the provision of collateral transformation. There is, however, an operational dependence associated with both client clearing and collateral transformation, since an investor's clearing agent may fail. We assume that client positions, collateral and collateral transformation transactions may be 'ported' – that is, transferred to a surviving bank – in the event that an investor's clearing agent defaults. If all banks default, there is no further scope for porting, at which point 'the system' defaults.

4.3.1 The adapted model

We introduce collateral transformation by assuming that each investor makes arrangements with a randomly selected bank to pledge a defined quantity of IA in exchange for HQLA. The bank, in turn, pledges the HQLA to the investor's counterparty (either a CCP or bilateral counterparty, depending on the clearing structure). The pledged IA remains on the investor's balance sheet, but appears as encumbered (IA*), while the HQLA pledged by the bank to the investor's counterparty appears as encumbered on the bank's balance sheet (HQLA*). Should the investor default on its obligation to its counterparty, the bank loses its pledged HQLA, but takes title over the investor's encumbered IA.

To manage the risk that the value of pledged IA changes, banks require that investors pledge a higher value of IA than the HQLA they loan in return. The difference between these values – the haircut, h – is designed to mitigate losses for a bank in the event that the price of IA falls relative to HQLA following the default of an investor. In the baseline case, h is assumed to be calibrated to cover 99 per cent of potential one-period IA price movements. That is, for investor i, with collateral requirements of C_i, the bank will have C_i of HQLA encumbered on its balance sheet, which has been posted to the CCP on behalf of the investor, and the investor will have $(1+h)C_i$ of IA encumbered on its balance sheet.

Stylised Balance Sheets
Percentage, following a collateral transformation transaction

Each bank		Each investor	
Assets	Equity and liabilities	Assets	Equity and liabilities
IA: $100 - C_i$	L: $100-k$	IA: $100 - (1+h)\,C_i$	K: 100
HQLA*: C_i	K: k	IA*: $(1+h)\,C_i$	

Should a bank default during the period, investors with which it has a collateral transformation relationship will be assigned (randomly) to one of the surviving banks.[14] In the event of an investor default, the bank loses the C_i in HQLA that it had encumbered on the investor's behalf and receives the $(1+h)\,(1+\Delta p_t^A)C_i$ in IA that the investor had encumbered on its balance sheet. If the price falls by a sufficiently large amount that it exceeds the haircut on the exposure, $(1+h)\,(1+\Delta p_t^A)<1$, the bank faces a 'collateral transformation loss', which is recorded as a reduction in HQLA and a corresponding reduction in equity.

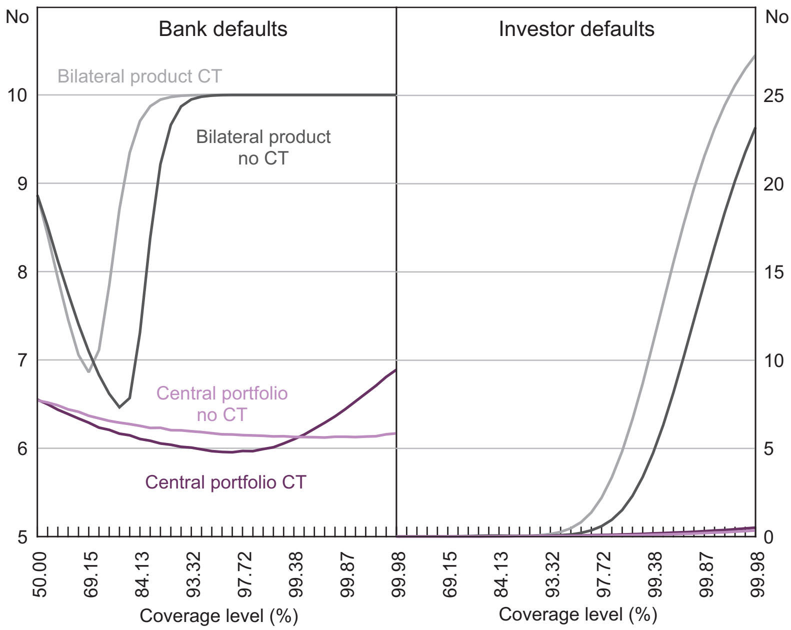
4.3.2 Results from the adapted model

The inclusion of collateral transformation in the model materially affects the results. As might be expected, the main effect of imposing restrictions on investors' access to liquidity and establishing new interconnections is to increase the probability of default due to illiquidity for both banks and investors. For a given clearing arrangement, introducing collateral transformation lowers the optimal level of collateral coverage (Figure 12, left-hand panel) and increases the incidence of

14 This increases the receiving bank's assets, which are funded by debt liabilities and equity in equivalent proportion to the original liability mix.

investor defaults (right-hand panel). Further, the U-shaped relationship between expected total bank defaults and collateral coverage becomes more prominent for central clearing when collateral transformation is introduced. Notwithstanding the greater netting efficiency of central clearing, at high levels of collateral coverage there is an increase in the incidence of investor defaults, in part due to the need to post a haircut with the bank that provides collateral transformation. The U-shaped curve nevertheless remains much flatter than for the clearing arrangements involving bilateral clearing, and minimum total expected bank defaults occur at a much higher level of collateral coverage.

Figure 12: Introducing Collateral Transformation
Expected number of defaults

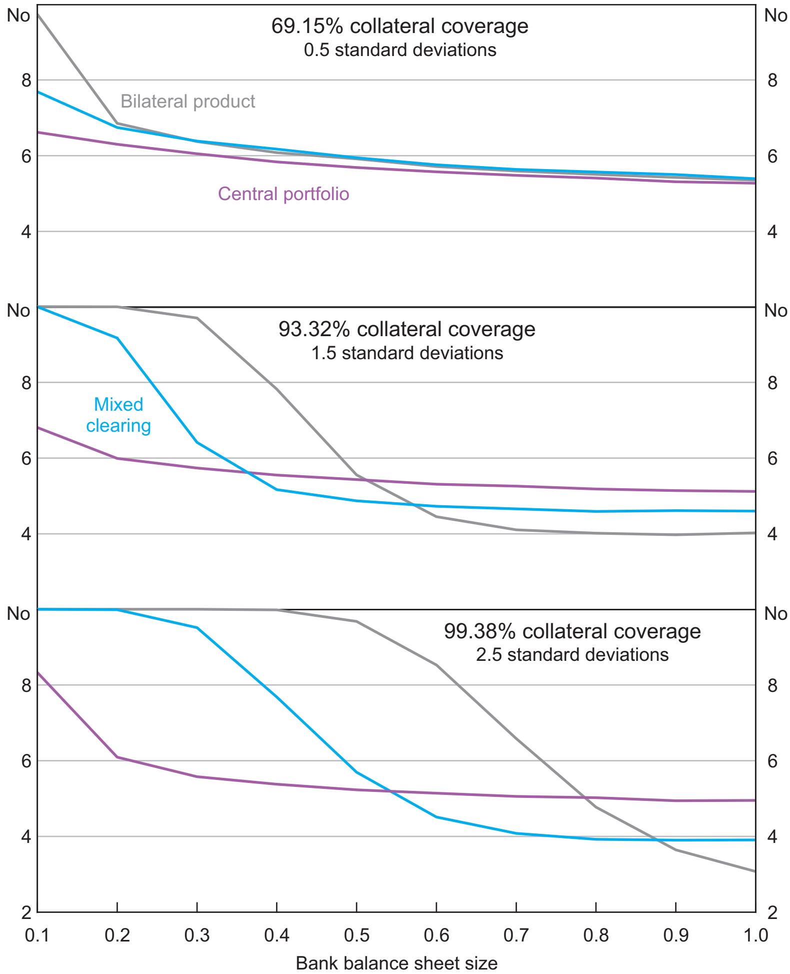


Notes: See notes to Figure 10

4.4 Varying parameter values

Given the stylised nature of the model, it is useful to consider the sensitivity of the results to changes in parameters to understand the mechanisms at play. The size and composition of balance sheets are particularly important because they determine the absolute value of IA available to be converted to HQLA: a larger balance sheet relative to the size of derivative positions allows more IA to be encumbered before liquidity strains arise. Figure 13 shows that the total expected number of bank defaults declines as the balance sheet size increases, but at a decreasing rate. Since bank equity is a defined percentage of liabilities, balance sheet size also determines the size of accumulated variation margin or collateral transformation losses that may be absorbed before a bank becomes insolvent. Unsurprisingly, as the share of equity increases, the minimum number of bank defaults observed under each clearing arrangement declines for a given balance sheet size and size of OTC derivative positions.

Figure 13: Balance Sheet Size and Collateral Coverage
Expected number of defaults



Notes: See notes to Figure 10; calculations are based on Monte Carlo simulation of the model with collateral transformation, with 25 000 iterations

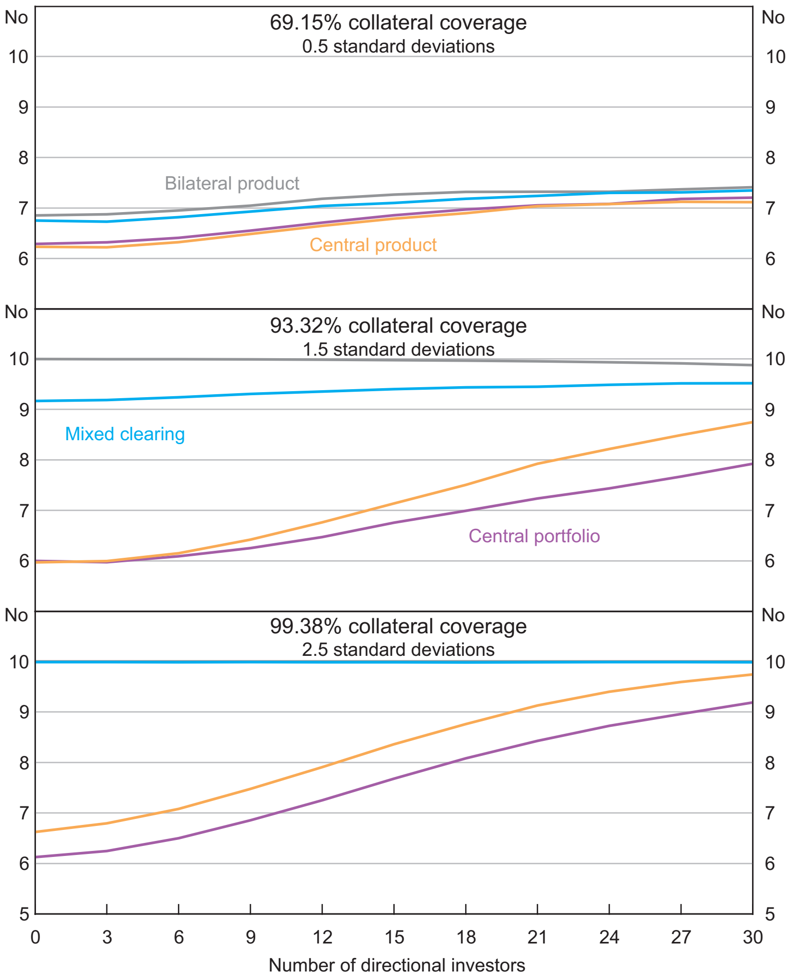
Assumptions about the volatility of prices also affect the results. As the volatility of derivative prices increases, collateral requirements increase and a bank has less capacity to absorb any variation margin or collateral transformation losses, again for a given balance sheet size. The volatility of IA prices is also an amplifier in the model. As IA price volatility increases, the minimum number of bank defaults observed for any given level of collateral coverage under each clearing arrangement also increases. At the same time, with higher volatility, larger falls in the price of IA may be observed. For both banks and investors, the incidence of such large falls 'squeezes' the stock of unencumbered assets on balance sheets and thereby reduces access to liquidity. As a result, even for the relatively collateral-efficient central clearing arrangements, the incidence of investor default rises with IA price volatility at higher levels of collateral coverage.

Another parameter that has been introduced in the dynamic model is the haircut on IA used as collateral to obtain HQLA. Because haircuts are used to mitigate the risk that the value of collateral will fall should it need to be liquidated, they are higher for assets with more volatile prices and that may be less likely to hold their value in stressed market conditions. Unsurprisingly, larger haircuts lead to a material reduction in the incidence of bank insolvency (for a given level of IA price volatility) in our model, particularly for centralised clearing arrangements. However, increasing haircuts will eventually increase the risk of investor default due to illiquidity. Haircuts therefore represent another channel by which dependence on the core for access both to clearing arrangements and HQLA may shift risk to the periphery.

Given that the prices of IA do not respond endogenously to changes in market conditions in the model, haircuts do not either. However, recent experience shows that increases in haircuts in response to rising price volatility were an important channel through which liquidity stresses were amplified and transmitted across financial markets. This was apparent in OTC derivative markets, and perhaps more dramatically in repo markets (Gorton and Metrick 2012). Indeed, the procyclicality of haircuts and the ability for this to amplify the effects of financial stress has been noted by policymakers as an area that deserves further consideration as a part of the regulatory reform agenda (CGFS 2009, 2010a).

Section 3.4.3 showed that if some subgroup of the periphery has directional derivative positions, the multilateral netting benefits of central clearing arrangements diminish. Figure 14 shows that this effect is also observed in the extended model. While for a given level of collateral coverage the expected incidence of bank defaults remains lower with central clearing, the steady rise in expected defaults as directionality increases is notable. Particularly striking is the finding that where margining in a centrally cleared setting is product based – or equivalently, where central clearing is fragmented across products – the incidence of bank defaults rises sharply at high levels of collateral coverage. An important driver of these results is the sharp increase in the incidence of illiquidity among investors as directionality increases. Once again, product-based margining or fragmentation in a centrally cleared setting significantly erodes the benefits of central clearing for investors, leaving the profile of investor defaults very similar to that in the mixed clearing setting.

Figure 14: Changing Directionality of the Periphery
Expected number of defaults



Notes: See notes to Figure 10; directionality is modelled as a draw from a half normal distribution with mean zero; all other parameters remain as in the baseline case in Figure 10; calculations are based on Monte Carlo simulation of the model with collateral transformation, with 25 000 iterations

4.5 Summary

While based on a highly stylised model, the results in this section underline the benefits of central clearing, while also drawing out the implications of higher collateral demand for financial stability. The analysis reveals a trade-off between the effect of collateral in reducing the risk of insolvency and its effect on agents' liquidity. In particular, we show that there is likely to be an optimal level of collateral coverage, which will depend on the netting efficiency of clearing arrangements, the extent to which margin methodologies take account of correlations between products, and the characteristics of products and agents.

This trade-off is accentuated when we assume that agents in the periphery have limited access to liquidity and rely on core banks' provision of collateral transformation services. The new interconnections arising from such dependence become an additional channel for contagion between the core and the periphery, and the haircuts imposed on investors in relation to collateral transformation transactions become an additional source of encumbrance which amplifies the liquidity risk that investors face.

5. Policy implications

The analysis presented in Sections 3 and 4 broadly supports some of the main arguments for increasing collateralisation and moving OTC derivative transactions to central clearing. However, the analysis also draws out some factors that might limit the effectiveness of these reforms. This gives rise to a number of policy messages that we consider under three headings: network structure (Section 5.1); optimal collateral coverage (Section 5.2); and collateral shortages (Section 5.3).

5.1 Network structure

The analysis in Sections 3 and 4 suggests that a disproportionate share of the netting benefits associated with central clearing will generally accrue to core institutions, and that the financial stability benefits of the OTC derivative reforms are likely to derive primarily from core institutions participating in central clearing and collateralisation. Indeed, the analysis raises the question whether the incremental benefits of collateralising trades executed with the periphery will outweigh the additional cost of the system's increased vulnerability to liquidity problems.[15] It may be that stability objectives could be best realised if collateralisation and central clearing requirements were imposed only on core institutions and the very largest peripheral institutions.[16]

Our analysis provides a framework for examining the relevant interactions, with three messages in particular emerging:

- *Product and agent characteristics*. The distribution of benefits depends on a number of factors, including: the size of positions in the periphery; the size of the core relative to the periphery; the number of derivative products; and the variance and covariance of both prices and positions across products. The directionality of positions in the periphery is particularly important, since this will have implications for the scope for multilateral netting of exposure in the centrally cleared scenarios. These characteristics should therefore be taken into account by policymakers when setting the scope of requirements around collateralisation and central clearing.

15 Although this paper takes the core-periphery structure as given, further insights into the costs and benefits of increasing the use of central clearing and collateralisation between the core and periphery may come from thinking about why this structure formed in the first place. Babus (2011) argues that a core will form endogenously for a network of OTC derivative transactions where long-term relationships are based on transaction fees and more *ad hoc* transactions require collateralisation. In this case, if transaction fees are lower than collateralisation rates, it pays for institutions that do not regularly transact with the same counterparty to form a long-term relationship with an intermediary (core) institution. If this model is correct, policymakers need to argue that the efficiency gains from intermediation are not sufficient to offset unmodelled costs, such as financial stability considerations, to justify some aspects of regulatory change.

16 This statement refers solely to netting and collateralisation. As noted in Section 2, central clearing may offer other benefits, such as standardisation, operational efficiencies, and centralised default management. These may, in some circumstances, deliver system-wide benefits if extended to certain peripheral institutions, particularly those with high trading volumes.

- *Cross-product netting*. To the extent that our representation of the core-periphery network structure is reasonable, the scope for the periphery to benefit from multilateral netting will be limited, even abstracting from directionality. If exposures between the core and periphery are nevertheless deemed to be sufficient in size to be relevant to financial stability, and therefore warrant being collateralised, it is important to minimise vulnerability to liquidity risk, by ensuring that clearing arrangements avoid excessive fragmentation and maximise the scope for cross-product offsets in setting margin requirements (to the extent that it is prudent to do so). For instance, market participants may select clearing arrangements that allow for margin offsets in portfolios of closely related OTC derivative products (e.g. offsets across interest rate products denominated in different currencies), or between OTC derivative products and closely related exchange-traded products (e.g. interest rate swaps and interest rate futures).
- *Collateral transformation*. As we have discussed, collateral transformation may emerge as a response to the increased demand for collateral arising from OTC derivative regulation if institutions (most notably, those in the periphery) caught by these regulations are not natural holders of collateral-eligible assets on their balance sheets. Our model suggests that where peripheral institutions have limited access to liquidity and rely on collateral transformation, the optimal level of collateral coverage is likely to be lower for all clearing arrangements. This should again be recognised in setting policy in this area and, given the potential additional stability risks that may emerge, policymakers should closely monitor the scale of such activity and intermediaries' risk management practices.

5.2 Optimal collateral coverage

Perhaps the most striking result in the model is the trade-off between insolvency and illiquidity as collateral coverage increases; that is, there is a point at which sourcing collateral-eligible securities and encumbering assets to meet collateral requirements creates liquidity strains that eventually offset the benefits from collateralisation in terms of reduced risk of insolvency. The model illustrates this trade-off with a very simple balance sheet structure. Nevertheless, notwithstanding the simplification, the results from our model underscore the increasing policy interest in asset encumbrance and the message that encumbrance to meet higher collateralisation requirements can be a source of vulnerability in the financial system (Debelle 2011; Haldane 2012; CGFS 2013; Gai *et al* this volume).

Using bank defaults as the metric for financial stability (recognising that with highly stylised agents and balance sheets, the numbers of defaults generated in the model should not be taken too literally) the model provides some clear qualitative guidance about the optimal level of collateral coverage under alternative clearing arrangements in a dynamic setting. In particular, the model demonstrates that more netting-efficient clearing arrangements allow the market to support a higher level of collateralisation – that is, the optimal trade-off between insolvency risk and illiquidity risk is observed at a higher level of collateral coverage. It may be, therefore, that the required level of collateral coverage for OTC derivative transactions in products that do not meet the prerequisites for central clearing (e.g. products that are insufficiently standardised, or cannot otherwise be effectively risk managed by a CCP) should be lower than that for transactions in centrally cleared products, precisely to reflect the higher risk of illiquidity in less netting-efficient bilateral arrangements.[17]

The model also suggests that questions around the optimal level of collateralisation should be considered in conjunction with decisions about the optimal level of bank equity. As noted in Section 4.4, both equity and collateral reduce the risk of bank default, so more mitigation through one channel suggests that the other form of mitigation can be used less actively. Importantly, however, these two channels have quite different implications for the distribution of risks. In particular, collateral is a 'defaulter pays' tool, which mitigates counterparty risk but can create liquidity risks, while equity is designed to absorb losses on a bank's own balance sheet. The cost of raising equity is not explicitly captured in our model, but in a richer setting it may be that an optimal mix of equity and collateral coverage would be observed.

5.3 Collateral shortages

The paper has assumed that there is no aggregate shortage of HQLA, and that an unlimited amount was available from an exogenous (un-modelled) Securities Market. This is likely to be a reasonable assumption in aggregate and in normal times. However, there are some jurisdictions, such as Australia, with shortages of domestic-currency HQLA, and, as the financial crisis demonstrated, when financial institutions have concerns about their access to liquidity and hoard HQLA on their balance sheets, it can be difficult to obtain HQLA at any price. Our model suggests that the increase in collateral demand associated with OTC derivative reform could lead to more frequent cases of short-term liquidity problems due to increased encumbrance.

In normal times, a shortage of HQLA will result in an endogenous price response, which could encourage an increase in supply. It has been argued that this mechanism was an important driver of the growth in HQLA supplied by the private sector in the mid 2000s, primarily through securitisation (Bernanke *et al* 2011; Pozsar 2011). The other obvious source of HQLA is government debt, which is more likely to hold its value in stressed financial market conditions because governments have the ability to raise revenue through taxation. However, as illustrated by recent events, debt sustainability considerations can place a limit on the ability of a sovereign to successfully create new HQLA through debt issuance (IMF 2012).

Another channel through which collateral shortages can be alleviated is through central bank policy. Central banks are the ultimate source of liquidity, and so the assumption that there is no liquidity shortage in the model implicitly requires that the central bank is monitoring conditions in funding markets for signs of stress, such as sharp increases in prices for HQLA, and is willing to respond. Central banks have a number of different tools available to them in this regard. In the case of short-term idiosyncratic liquidity shortages, the most appropriate tool is collateralised lending at a penalty rate through the discount window.

A more generalised liquidity shortage that manifests as an increase in demand for HQLA and falling prices for less-liquid assets requires a different solution. Central banks can increase system

17 New international standards for initial margining of non-centrally cleared OTC derivatives, by contrast, envisage a level of collateral coverage equivalent to that under central clearing (see Section 2.2 and BCBS-IOSCO (2013)). An important consideration in developing these standards has been to incentivise central clearing by ensuring that there is no collateral cost advantage to bilateral clearing. For products that do not meet the prerequisites for central clearing, however, these incentives will not be relevant.

liquidity through collateralised lending in their standard market operations. However, Singh and Stella (2012) observe that this may be ineffective at alleviating generalised liquidity stresses if central banks attempt to increase liquidity by lending against collateral for which there is excess demand. In this case, central banks can only increase liquidity by lending against assets that are relatively illiquid and are experiencing excess supply. This will typically involve broadening the set of assets that are eligible as collateral in central bank operations, which may be done to increase liquidity in specific, potentially systemically important, asset markets. In conditions of more severe market dysfunction, it may be necessary for central banks to purchase illiquid assets outright to minimise fire sales and support prices for distressed assets. These actions were taken in a number of jurisdictions during the course of the financial crisis.

Central banks may also take actions to alleviate liquidity stresses that arise because the distribution of the supply of HQLA and the distribution of demand do not match up. In the model presented in Section 4, this is characterised by the banks in the core having direct access to HQLA, while institutions in the periphery do not. This may arise, for instance, because institutions in the periphery do not have direct access to the central bank. In a domestic context, a central bank can affect the distribution of HQLA by broadening the set of counterparties to which it is willing to lend on a collateralised basis, or making lending to core banks conditional on providing liquidity to some subsets of the periphery.

The distribution of HQLA can also become problematic if the excess demand is for HQLA that is not denominated in domestic currency. In this case, the local central bank is not the ultimate source of liquidity. This situation did occur during the financial crisis (CGFS 2010b), and could arise in the OTC derivative market, given its global nature. In particular, there could be extensive use of non-domestic CCPs, particularly by institutions in the periphery, in order to maximise netting benefits and minimise fragmentation (as discussed in Section 5.1). In this circumstance, the policy options include swap facilities between central banks. This proved to be an effective way for central banks to provide liquidity in a non-domestic currency, and for the originating central banks to minimise their exposure to institutions about which they potentially had very little information.

6. Conclusions

With national jurisdictions currently well advanced in the implementation of G20 commitments around collateralisation and central clearing of OTC derivatives, this paper has considered the important question of how differences in the characteristics of agents and products might in some circumstances have implications for the effectiveness of the reforms. The paper has done so by modelling the system as a core-periphery network of banks and investors, and has examined how network structure might affect netting efficiency and collateral demand under alternative clearing arrangements. It has also considered new sources of interdependence between the core and periphery; in particular, by assuming that restricted access to liquidity for the periphery requires that investors source HQLA from the core via collateral transformation.

The paper has drawn out a number of key messages, relevant to the ongoing policy debate on implementation of the reforms. Most notably, the paper has illustrated how network structure and the size and nature of peripheral exposures – e.g. small, directional positions with the core – may limit netting opportunities for the periphery and may increase their vulnerability to liquidity risk in collateralised bilaterally or centrally cleared settings. In this sense, when considering the implications of higher collateral demand, it is important to look beyond the aggregate availability of HQLA to also consider the distribution. Given the stylised nature of the model, further work is needed to strengthen the conclusions, including: enriching the representation of agents' balance sheets; endogenising the price of illiquid assets; and calibrating model parameters to real world observations, so as to better establish the economic relevance of the results.

References

Anand K, J Chapman and P Gai (2012), 'Covered Bonds, Core Markets, and Financial Stability', Humboldt University, Collaborative Research Center, SFB 649 Discussion Paper 2012-065.

Babus A (2011), 'Endogenous Intermediation in Over-the-Counter Markets', unpublished manuscript, Imperial College London. Available at <http://www.anababus.net/research/otc.pdf>.

BCBS (Basel Committee on Banking Supervision) (2012), *Results of the Basel III Monitoring Exercise as of 31 December 2011*, Bank for International Settlements, Basel.

BCBS-IOSCO (Board of the International Organization of Securities Commissions) (2013), *Margin Requirements for Non-Centrally Cleared Derivatives: Second Consultative Document*, Bank for International Settlements, Basel.

Bech ML and E Atalay (2010), 'The Topology of the Federal Funds Market', *Physica A: Statistical Mechanics and its Applications*, 389(22), pp 5223–5246.

Bernanke BS, C Bertaut, L Pounder DeMarco and S Kamin (2011), 'International Capital Flows and the Returns to Safe Assets in the United States, 2003–2007', Board of Governors of the Federal Reserve System, International Finance Discussion Paper No 1014.

Brunnermeier MK and LH Pedersen (2009), 'Market Liquidity and Funding Liquidity', *The Review of Financial Studies*, 22(6), pp 2201–2238.

Cecchetti SG, J Gyntelberg and M Hollanders (2009), 'Central Counterparties for Over-The-Counter Derivatives', *BIS Quarterly Review*, September, pp 45–58.

CGFS (Committee on the Global Financial System) (2009), *The Role of Valuation and Leverage in Procyclicality*, CGFS Papers No 34, Bank for International Settlements, Basel.

CGFS (2010a), *The Functioning and Resilience of Cross-Border Funding Markets*, CGFS Papers No 37, Bank for International Settlements, Basel.

CGFS (2010b), *The Role of Margin Requirements and Haircuts in Procyclicality*, CGFS Papers No 36, Bank for International Settlements, Basel.

CGFS (2013), *Asset Encumbrance, Financial Reform and the Demand for Collateral Assets*, CGFS Papers No 49, Bank for International Settlements, Basel.

Cox N, N Garvin and G Kelly (2013), 'Central Counterparty Links and Clearing System Exposures', RBA Research Discussion Paper No 2013-12.

CPSS-IOSCO (Committee on Payment and Settlement Systems and Technical Committee of the International Organization of Securities Commissions) (2012), *Principles for Financial Market Infrastructures*, Bank for International Settlements, Basel.

Craig B and G von Peter (2010), 'Interbank Tiering and Money Center Banks', BIS Working Papers No 322.

Debelle G (2011), 'The Present and Possible Future of Secured Issuance', Address to the Australian Securitisation Forum Annual Conference, Sydney, 21 November.

Duffie D, A Li and T Lubke (2010), 'Policy Perspectives on OTC Derivatives Market Infrastructure', Federal Reserve Bank of New York Staff Report No 424.

Duffie D and H Zhu (2011), 'Does a Central Clearing Counterparty Reduce Counterparty Risk?', *The Review of Asset Pricing Studies* 1(1), pp 74–95.

Ellis R (2012), 'Collateral Transformation: Liquidity and Market Risk Issues', White paper, Sapient Global Markets.

ESRB (European Systemic Risk Board) (2012), 'Macro-Prudential Stance on Eligible Collateral for Central Counterparties in Response to a Consultation by ESMA – Based on Article 46 of the EMIR Regulation', Accompanying document to ESRB/2012/3.

FSB (Financial Stability Board) (2010), 'Implementing OTC Derivatives Market Reforms', 25 October.

Gai P, A Haldane and S Kapadia (2011), 'Complexity, Concentration and Contagion', *Journal of Monetary Economics*, 58(5), pp 453–470.

Gorton G and A Metrick (2012), 'Securitized Banking and the Run on Repo', *Journal of Financial Economics*, 104(3), pp 425–451.

G20 (Group of Twenty) (2009), 'Leaders' Statement: The Pittsburgh Summit', 24–25 September.

Haldane A (2012), 'Financial Arms Races', Speech at the Institute for New Economic Thinking, The Centre for International Governance Innovation, and the Mercator Research Institute on Global Commons and Climate Change Third Annual Plenary Conference 'Paradigm Lost: Rethinking Economics and Politics', Berlin, 12–15 April.

Heath A and MJ Manning (2012), 'Financial Regulation and Australian Dollar Liquid Assets', RBA *Bulletin*, September, pp 43–52.

Heller D and N Vause (2011), 'Expansion of Central Clearing', *BIS Quarterly Review*, June, pp 67–81.

IMF (International Monetary Fund) (2012), *Global Financial Stability Report: The Quest for Lasting Stability*, World Economic and Financial Surveys, IMF, Washington DC.

ISDA (International Swaps and Derivatives Association) (2012), 'Initial Margin for Non-Centrally Cleared Swaps: Understanding the Systemic Implications', November.

Jackson JP and MJ Manning (2007), 'Comparing the Pre-Settlement Risk Implications of Alternative Clearing Arrangements', Bank of England Working Paper No 321.

Kiyotaki N and J Moore (1997), 'Credit Cycles', *Journal of Political Economy*, 105(2), pp 211–248.

Manning MJ, A Heath and J Whitelaw (2010), 'The Foreign Exchange Market and Central Counterparties', RBA *Bulletin*, March, pp 49–57.

Markose SM (2012), 'Systemic Risk from Global Financial Derivatives: A Network Analysis of Contagion and Its Mitigation with Super-Spreader Tax', IMF Working Paper WP/12/282.

Pirrong C (2012), 'Clearing and Collateral Mandates: A New Liquidity Trap?', *Journal of Applied Corporate Finance*, 24(1), pp 67–73.

Pozsar Z (2011), 'Institutional Cash Pools and the Triffin Dilemma of the U.S. Banking System', IMF Working Paper No WP/11/190.

Sidanius C and F Zikes (2012), 'OTC Derivatives Reform and Collateral Demand Impact', Bank of England Financial Stability Paper No 18.

Singh M (2011), 'Velocity of Pledged Collateral: Analysis and Implications', IMF Working Paper No WP/11/256.

Singh M (2013), 'The Changing Collateral Space', IMF Working Paper No WP/13/25.

Singh M and P Stella (2012), 'Money and Collateral', IMF Working Paper No WP/12/95.

Tabb A (2012), 'Optimizing Collateral: In Search of a Margin Oasis', TABB Group Vision Note, June.

Upper C and A Worms (2004), 'Estimating Bilateral Exposures in the German Interbank Market: Is There a Danger of Contagion?', *European Economic Review*, 48(4), pp 827–849.

Discussion

1. Kevin Davis

The paper by Alexandra Heath, Gerard Kelly and Mark Manning does an excellent job of extending existing models of the effects of requiring use of CCPs for OTC derivatives on counterparty risk and implications for collateral demand. The innovations include: first, considering a particular market structure where there are core institutions in the OTC markets that also trade with and provide services to a periphery of other participants; second, allowing for differential involvement of the core and periphery in CCPs; and third, introducing the role of collateral requirements for initial and variation margins.

The results of the stylised model reinforce and extend a number of themes coming out of recent literature. First, the benefits from netting exposures via CCPs are offset to the extent that there is a loss of netting available under bilateral arrangements. In the core-periphery model, netting benefits from CCPs accrue primarily to the core. Second, collateral implications are important and depend upon a variety of factors including the mix of CCP and bilateral clearing, and upon the way in which initial and variation margins are determined. Third, illiquidity and the inability to meet margin calls due to assets being encumbered and not convertible into liquid assets, are a potential source of bank failure in addition to insolvency. And while higher collateral requirements reduce the risk of failure by reducing counterparty risk, they increase the risk of illiquidity. Fourth, if banks in the 'core' provide collateral transformation services to other investors (essentially a securities lending agreement involving provision of high-quality liquid assets (HQLA) in return for illiquid assets), new linkages and sources of failure arise.

As with any stylised model, questions arise about how much the results depend on particular assumptions, and whether they are generalisable to a more realistic depiction of the real world. (And it should, of course, be noted that even modelling the hypothetical 'simple' world of the paper is far from being a simple task. In that regard, I should commend the authors for their success in presenting their modelling and results in a way which should be accessible to even those readers without particular expertise in these arcane and complex features of modern financial markets.)

As regards the modelling, I have only a few comments and suggestions. First, the authors assume that investors in the periphery cannot become insolvent because they are all equity financed and thus unlevered. But, to the extent that they are entering derivative contracts they are *de facto* levered. I think, however, that the calibration of the model makes this a good debating point, but not important to the results.

Second, they assume that should an investor in the periphery default on a derivatives obligation to a counterparty (either a bilateral counterparty or a CCP), the bank that has provided it with HQLA may suffer a loss. This arises if the value of collateral is less than the HQLA the bank had provided for the investor – and occurs if an adverse move in the price of the collateral (the illiquid asset) has occurred which is greater than the safety margin arising from the initial haircut required on the collateral. There are, I think, two issues here. First is the question of why the bank would not have incorporated margin calls into the collateral transformation arrangement to prevent this outcome. Second, why would the bank not have some recourse to the illiquid assets of the investor in this case – I wouldn't have thought that the banks would be that charitable!

A third issue relates to the modelling (or lack thereof) of the HQLA market and the specification of eligible collateral. The authors at some point refer to variation margins being paid in 'cash' but in general assume the HQLA used as collateral are securities. Two comments may be relevant here. First, why wouldn't CCPs (or others) accept illiquid assets as collateral, subject of course to suitable haircuts and margining? If such assets are good enough for the Reserve Bank in its repo transactions, why aren't they good enough for the CCPs?

The authors do address the issue of HQLA supply considerations in their policy discussion. But missing from that discussion (and more generally) is an analysis or description of the business model and objectives of the CCP and how they might affect decisions such as acceptability and quantum of various assets as collateral. I do note that there is a comment (see p 58, footnote 11) that banks in the core may bear losses as the mutual owners of a CCP if there is inadequate variation (and initial) margin held by the CCP. (As a digression, that perhaps suggests that in the discussion of who benefits most from netting of exposures, banks or investors in the periphery, perhaps the exposures of the CCP should be treated as bank exposures. If so, the conclusion that banks benefit more than the periphery is no longer so apparent). The second comment relating to collateral is to ask whether it could be the case that the CCP might take as collateral 'cash' in the form of payments into an account it has with the central bank? Is that feasible, and what implications might it have?

Two further issues regarding the modelling warrant mention (and would require much more work to follow up on). First, it would be interesting to see some attempt at calibrating the model to real world parameters. While the model outlines the sensitivity of risk and failures to particular features of the model, what is the economic significance of these in a more realistic setting? Second, how well does the model generalise to the case of many derivatives rather than just two as assumed?

The authors address a number of policy issues in Section 5 of the paper including: network structure; optimal collateral coverage; and collateral shortages. Some of my earlier comments relate to the last of these issues, and my only other comment directly related to those policy issues is to ask the question: why, if some variants of the CCP arrangements are Pareto improving as the paper seems to suggest, they don't arise naturally more often? Perhaps it's because even in this stylised world it's hard enough to fully understand the intricacies and outcomes of such arrangements, and even more difficult in the arcane and complex world of modern finance.

I do have one other policy issue. The model involves banks failing, due to insolvency or illiquidity, but the paper does not discuss how that actually takes place. What role is there for the regulator in managing the exit of the banks and how should the regulator take into account the default and illiquidity risks arising from the OTC exposures and collateral transformation activities? And I suspect that all of the institutions in the core are systemically important financial institutions (SIFIs), so what does this imply about potential failure arrangements or other regulatory requirements? Or will use of CCPs remove some of these institutions from SIFI status?

In conclusion, I think this paper makes a valuable contribution to helping us understand some of the implications of current trends and policy issues in the structure of clearing and collateral arrangements. It is a complex, and developing, area and the authors have done a good job in highlighting some of the important issues in a clear and understandable way.

2. General Discussion

The discussion began with a participant noting that the model appeared to be in partial equilibrium and that incorporating general equilibrium dynamics could substantially alter the model's implications. Specifically, they noted that reductions in risk from the implementation of CCP clearing could encourage banks to substitute into higher risk, higher return activities, such that the overall effect on risk may wash out. Alex Heath confirmed that the model was not in general equilibrium, and agreed that this was an interesting direction to consider in future work.

Further discussion stemmed from Kevin Davis's question about why CCPs had not arisen organically but had largely come about only as the result of regulatory intervention. One participant postulated that this observation suggested that individual financial institutions might not have an incentive to join a CCP if this increased transparency because core banks might be able to use informational advantages in a more opaque environment to increase their profits. This participant also suggested that policymakers should want some lending to remain uncollateralised because this encouraged interbank monitoring.

Another participant raised the potential for agency issues to arise with CCPs, and inquired about their incentive structures and business models. In particular, it was noted that much of the reduction in individual risk was achieved by transferring exposure onto the CCP, which potentially created systemic risk. Another participant suggested there was no prospect of a CCP becoming insolvent when haircutting variation margin was an option. Mark Manning agreed, observing the model mimicked variation margin haircutting because CCP exposures and losses were allocated back to banks, so the CCP itself could not actually fail. From a normative policy perspective, he stated that the optimal CCP business model was unclear at present, and that progress on this front would require the CCP to be modelled more explicitly.

Several other participants suggested further scope for the development of the model. A few participants commented that it would be interesting and useful to use real data to calibrate the model. This would provide clearer guidance on the economic importance of some of the mechanisms highlighted by the stylised model in the paper. Another participant suggested that it would be worthwhile to investigate whether clearing only a limited range of swap types might actually increase exposure. Yet another participant suggested that the results in the paper could be interpreted as suggesting that the stability gains from central clearing were much smaller for countries such as Australia, with most of the benefits accruing to parties in the core. They concluded that the efficiency versus stability trade-off was much less clear-cut for Australia. This was followed by a suggestion that the core-periphery model could be extended to include a sub-core on the basis that this would make the policy implications of central clearing for non-core countries like Australia clearer. Mr Manning concurred that Australian banks were core in their own market, and that the relevant peripheral institutions in this case were non-dealers, or investors. The authors generally agreed that a more detailed model would need to be developed before it could be used to underpin policy recommendations, and confirmed that further work along these dimensions was planned.

Financial Markets, Institutions and Liquidity

Franklin Allen and Elena Carletti*

1. Introduction

One important reason for the global impact of the 2007–2009 financial crisis was massive illiquidity in combination with an extreme exposure of many financial institutions to liquidity needs and market conditions. As a consequence, many financial instruments could not be traded anymore; investors ran on a variety of financial institutions, particularly in wholesale markets; financial institutions and non-financial firms started to sell assets at fire sale prices to raise cash; and central banks all over the world injected huge amounts of liquidity into financial systems.

But what is liquidity and why is it so important for financial institutions and firms to command enough liquidity? In this paper we consider liquidity from a number of different perspectives and consider how the academic literature has evolved in light of developments in funding markets and their liquidity during the crisis that started in 2007. We start in Section 2 with a discussion of funding liquidity for banks and financial institutions. We review the literature before the crisis on deposits as a funding mechanism for banks, which was traditionally what the literature on financial stability focused on. This was because most historical financial crises involved the withdrawal of money from deposit accounts and the hoarding of this cash. We next consider interbank markets. There is a large literature on liquidity in these markets and how they operate. There are also many papers that consider their role in propagating contagion. The literature before the crisis is surveyed and then recent contributions made since the crisis are discussed. We argue that deposit insurance to a large extent solved the problem of runs by retail investors. In fact, deposits were one of the most stable forms of finance during the crisis. However, going forward this may not be the case as the credibility of deposit insurance depends on the extent of guarantees and the fiscal position of the government. In contrast, interbank markets were heavily affected by the crisis and in many cases froze. It seems that asymmetric information played an important role and a number of theories based on asymmetric information have been developed to explain market freezes.

Section 3 considers funding markets for firms. Important theories of liquidity management were developed by Holmström and Tirole (1998) and Gorton and Huang (2004). Funding for firms was not as disrupted during the crisis as funding for banks and other financial institutions. However, one of the important implications of these theories is that there may be a shortage of safe liquid assets for firms to manage their liquidity needs and that governments may need to intervene to supply such assets. It seems that there was in fact a shortage of these assets. Instead of government securities, the market supplied securitised mortgages. Although most tranches were rated AAA by the credit rating agencies, these securities were not in fact safe. When house prices began to fall, this became clear and this triggered the crisis.

* We thank participants for helpful comments.

Section 4 considers the funding markets for real estate. Despite the importance of real estate in triggering previous financial crises, relatively little attention has been paid to these funding markets in the literature compared with those for financial institutions and firms. However, as indicated above, securitised mortgages played a very important role in triggering the crisis.

The disruption of so many funding markets led to intervention in many markets by central banks (Section 5). Although the literature has for many years considered the role of central banks as lenders of last resort (LOLR), other kinds of intervention were not anticipated or analysed. The academic literature has only just begun to consider the different kinds of interventions that central banks should undertake when funding markets break down. The other aspect of central bank policy that has not fully been analysed is the effect of low interest rates and quantitative easing on asset prices. The effect of withdrawing these measures and returning to a normal interest rate regime is also not well understood. Finally, Section 6 concludes.

The paper draws on discussions of the literature in Allen, Babus and Carletti (2009), Allen *et al* (2011) and Allen and Carletti (2013).

2. The Funding of Financial Institutions

2.1 Views before the crisis

2.1.1 Bank deposits

The most important type of financial institution is the bank. Historically banks were mostly funded by deposits. Much of the traditional literature on financial crises has focused on bank runs where depositors withdraw their money and hoard cash. There are two theories to explain the origins of banking crises. One line of argument maintains that they are undesirable events caused by random deposit withdrawals unrelated to changes in the real economy. In the influential work of Bryant (1980) and Diamond and Dybvig (1983) bank runs are self-fulfilling prophecies. In these models, agents have uncertain needs for consumption in an environment in which long-term investments are costly to liquidate. If depositors believe that other depositors will withdraw then all agents find it rational to redeem their claims and a panic occurs. Another equilibrium exists where everybody believes no panic will occur and agents withdraw their funds according to their consumption needs. In this case, their demand can be met without costly liquidation of assets.

The second set of theories of banking crises posit that they are a natural outgrowth of the business cycle. An economic downturn will reduce the value of bank assets, raising the possibility that banks are unable to meet their commitments. If depositors receive information about an impending downturn in the cycle, they will anticipate financial difficulties in the banking sector and try to withdraw their funds, as in Jacklin and Bhattacharya (1988). This attempt will precipitate the crisis. According to this interpretation, crises are not random events but a response of depositors to the arrival of sufficiently negative information on the unfolding economic circumstances. This view is consistent with the evidence in Gorton (1988) that in the United States in the late 19th and early 20th centuries, a leading economic indicator based on the liabilities of failed businesses could accurately predict the occurrence of banking crises.

One strand of the business cycle explanation of crises emphasises the role of information asymmetry in triggering a banking crisis. In this view, a panic is a form of monitoring. Chari and Jagannathan (1988) focus on a signal extraction problem where some depositors withdraw money for consumption purposes while others withdraw money because they know that the bank is about to fail. In this environment, depositors may also withdraw because they cannot distinguish whether there are long lines at banks because of consumption needs or because informed depositors are getting out early. Chari and Jagannathan show crises occur not only when the outlook is poor but also when liquidity needs are high despite there being no new information on future returns.

Building on the empirical work of Gorton (1988), Allen and Gale (1998) develop a model that is consistent with the business cycle view of the origins of banking crises. They assume that depositors can observe a leading economic indicator that provides public information about future bank asset returns. If these returns are expected to be high then depositors are quite willing to keep their funds in the bank. However, if returns are expected to be sufficiently low, they will withdraw their money and there is a crisis.

Calomiris and Kahn (1991) show that the threat of bank liquidation disciplines the banker when he can fraudulently divert resources *ex post*. The first-come, first-served constraint provides an incentive for costly information acquisition by depositors. Calomiris and Kahn regard bank runs as always beneficial since they prevent fraud and allow the salvage of some of the bank's value. Diamond and Rajan (2001) develop a model in which banks have special skills to ensure that loans are repaid. By issuing demand deposits with a first-come, first-served feature, banks can pre-commit to recoup their loans. This allows long-term projects to be funded and depositors to consume when they have liquidity needs. However, this arrangement leads to the possibility of a liquidity shortage in which banks curtail credit when there is a real shock.

While the multiple equilibria theory of bank runs explains how panics may occur, it is silent on which of the two equilibria will be selected. Depositors' beliefs are self-fulfilling and are coordinated by 'sunspots'. Sunspots are convenient pedagogically but they do not have much predictive power. Since there is no real account of what triggers a crisis, it is difficult to use the theory for any policy analysis. The business cycle theory also has panic runs as well as fundamental runs. Again there is no natural way to choose the equilbrium.

A selection mechanism that applies to this type of coordination game is introduced in Carlsson and van Damme (1993). The authors analyse incomplete information games where the actual pay-off structure is randomly drawn from a given class of games and where each player makes a noisy observation of the game to be played. Such games are called global games. In a global games setting, the lack of common knowledge about the underlying pay-off structure selects the risk dominant equilibrium as the unique equilibrium of the game. Morris and Shin (1998) successfully apply this approach to coordination games in the context of currency crises, when there is uncertainty about economic fundamentals. Rochet and Vives (2004) and Goldstein and Pauzner (2005) have used global games to study banking crises. Global games represent a nice combination of the multiple equilibria and business cycle approaches to panics. The equlibrium selected is unique and there are both fundamental and panic runs. An important contribution by Chen, Goldstein and Jiang (2007) establishes the empirical applicability of the global games approach. The authors develop a global games model of mutual fund withdrawals, where strategic complementarities among investors generate fragility in financial markets. Using a detailed dataset, they find that, consistent with their model, funds with illiquid assets exhibit stronger sensitivity of outflows to bad past performance than funds with liquid assets.

Deposit funding plays a significant role in the theoretical literature on financial crises because historically crises have involved the withdrawal of money from banks and the hoarding of cash. However, the widespread introduction of deposit insurance meant that deposits became one of the more stable forms of funding during the recent crisis, as we shall see. We turn next to another form of funding that was important in the theoretical literature and the breakdown of which played an important role in the crisis.

There is a large empirical literature on banking crises. Friedman and Schwartz (1963) have written a comprehensive monetary history of the United States from 1867–1960. Friedman and Schwartz argue that the crises were panic-based, as evidenced by the absence of downturns in the relevant macroeconomic time series prior to the crises. This contrasts with Gorton's (1988) evidence that banking crises in the National Banking Era were predictable, which suggests banking crises are related to the business cycle. Calomiris and Gorton (1991) provide a wider range of evidence that crises are grounded in fundamentals. Wicker (1980, 1996) shows that, despite the absence of collapses in US national macroeconomic time series, in the first two of the four crises identified by Friedman and Schwartz in the early 1930s there were large regional shocks. The authors attribute the crises to these shocks. Calomiris and Mason (2003) undertake a detailed econometric study of these four crises using a broad range of data and conclude that the first three crises were fundamentals-based while the fourth was panic-based.

2.1.2 Interbank markets

In recent decades interbank markets have come to play an increasingly significant role in the funding of banks. Ideally, these markets should ensure an efficient liquidity transfer between surplus and needy banks. They are the focus of central banks' implementation of monetary policy and a smooth functioning of interbank markets is essential for maintaining the stability of the overall financial system. Despite this key role and the potentially significant effect their functioning has on the whole economy, there was not a large literature studying interbank markets prior to the crisis.

Bhattacharya and Gale (1987) is the pioneering theoretical study in this area. They analyse a setting in which individual banks face privately observed liquidity shocks due to a random proportion of depositors wishing to make early withdrawals. In addition, each bank has private information about the liquid fraction of its portfolio. Since the liquidity shocks are imperfectly correlated across intermediaries, banks coinsure each other through an interbank market. Bhattacharya and Gale show that, even in the absence of an aggregate liquidity shock for the intermediary sector as a whole, banks are induced to under-invest in liquid assets and free-ride on the common pool of liquidity because of the lower return that liquid assets yield. A central bank can mitigate this problem by (even imperfectly) monitoring banks' asset choices. However, the authors argue that one would not expect to achieve the first-best, as in such an asymmetric information setting it seems unrealistic to assume that a central bank can elicit perfect knowledge of the quality of the assets across all banks' portfolios.

The Bhattacharya-Gale model provides a foundation for the analysis of the functioning of financial markets and financial intermediaries, optimal liquidity provision and financial fragility. One line of research that was developed aims to provide a deeper and more general understanding of the interaction of financial markets and financial intermediaries. In the Bhattacharya-Gale setup, the characterisation of interbank markets is quite rudimentary and, in addition, interbank markets are not part of an optimal arrangement. Thus, it is important to have a framework with a role for both financial intermediaries and for markets, modelled from first principles. Allen and Gale (2004a, 2004b, 2007), among others such as Diamond (1997) and Fecht (2004), develop such an approach. They argue that in modern financial systems financial markets and financial intermediaries are complementary. As in Diamond and Dybvig (1983), intermediaries provide an insurance function to consumers against their individual liquidity shocks. However, individual investors cannot trade directly in the full range of markets since it is too costly for them due to information and transaction costs. This is the reason why markets also play an important role in this environment. Markets allow financial intermediaries (and hence their depositors) to share risk. Intermediaries such as banks and mutual funds can invest in financial markets. They provide risk-sharing services by packaging existing claims on behalf of investors who do not have access to markets and, of course, are trading these claims on markets. Such a general equilibrium framework allows a normative analysis of liquidity provision by the financial system.

Consumers deposit funds into banks which provide liquidity insurance such that depositors can withdraw whenever they have liquidity needs. Banks accumulate the funds and lend them to firms to fund long-term investments. There are two types of uncertainty concerning liquidity needs which makes liquidity management on the part of banks quite difficult. The first is that each bank is exposed to idiosyncratic liquidity risk. At any given date its customers' liquidity needs may be higher or lower than expected. The second type of uncertainty is the aggregate liquidity risk which banks have to face. In some periods system-wide liquidity demand is high while in others it is low, thereby exposing all banks to the same shock at the same time.

What Allen and Gale analyse in this framework is the ability of banks to hedge themselves against these liquidity shocks. They show in Allen and Gale (2004b) that this crucially depends on the completeness of financial markets. If markets are complete, in the sense that for each aggregate state an Arrow security can be traded, then the financial system provides liquidity efficiently as it ensures that banks' liquidity shocks are hedged. In particular, they show that in an environment with complete markets and in which intermediaries can offer complete contingent contracts, the resulting allocation is incentive-efficient. With complete contracts, the consequences of default will be anticipated and therefore included in the contract, so default and financial crises do not occur. If intermediaries can only offer incomplete contracts – a case in point is where banks only offer deposit contracts – default can improve welfare by improving the contingency of contracts. Thus, financial crises do occur in such a model, but are not necessarily a source of market failure. Hence, even in this case with incomplete contracts, the financial system provides optimal liquidity and risk sharing if markets for aggregate risks are complete. A set of complete and perfect financial markets, which includes interbank markets, is necessary for the efficient functioning of the financial system. However, missing markets may provide a role for government intervention. If markets are incomplete, then there may be too much or too little liquidity and government regulation may be welfare-improving.

Allen and Gale (2004a) explore in further detail interesting ramifications of this framework. By using a simplified version of the general equilibrium model introduced in Allen and Gale (2004b), they investigate the role of liquidity in determining asset prices. The incompleteness of markets leads to inefficient provision of liquidity by the financial system. This can generate cash-in-the-market pricing, which implies that the prices of long-term safe assets can fall below their fundamental value. This leads to financial fragility, which means that even small shocks can have large price effects and this can lead to financial crises.

An important contribution to the literature on interbank markets is that of Freixas and Holthausen (2004). They analyse the scope for international interbank market integration when cross-border information about banks is less precise than home-country information. The timing of consumption needs generates liquidity shocks for the banks, both at the individual and at the aggregate level. Banks can cope with these shocks by investing in a storage technology or can use the interbank market for channelling liquidity. The authors look at secured repo and unsecured interbank lending markets, since both allow banks to cope with liquidity shocks, and they consider under what conditions segmented or integrated international interbank markets exist. They show that a segmented interbank market is always an equilibrium, while the emergence of an integrated international market depends on the quality of cross-border information. Only if cross-border information is sufficiently precise is integration of markets possible.

2.1.3 Contagion and interbank markets

Another important aspect of the operation of interbank markets is the possibility for financial contagion that they introduce. Financial contagion refers to the process by which a shock in one part of the financial system spreads to other parts through a series of 'interlinkages'. The literature on contagion takes two approaches: examining direct linkages and indirect balance-sheet linkages. In looking for contagious effects via direct linkages, research by Allen and Gale (2000) studies how the banking system responds to contagion when banks are connected under different network structures. Banks perfectly insure against liquidity shocks by exchanging interbank deposits. The connections created by swapping deposits, however, expose the system to contagion. The authors show that incomplete networks are more prone to contagion than complete structures. Better-connected networks are more resilient since the losses incurred on one bank's portfolio are shared with more banks through interbank agreements. To show this, they take the case of an incomplete network where the failure of a bank may trigger the failure of the entire banking system. They prove that, for the same set of parameters, if banks are connected in a complete structure, then the system is more resilient with regard to contagious effects.

The research that followed, although using stylised models, captured well the network externalities created from individual bank risk. Freixas, Parigi and Rochet (2000) consider the case of banks that face liquidity shocks due to uncertainty about where consumers will withdraw funds. In their model, the connections between banks are realised through interbank credit lines that enable these institutions to hedge regional liquidity shocks. As in Allen and Gale's study, more interbank connections enhance the resilience of the system to the insolvency of a particular bank. One drawback is that this weakens the incentives to close inefficient banks. Moreover, the authors find that the stability of the banking system depends crucially on how many depositors choose to consume at the location of a bank that functions at a money centre.

Concerned with the optimal financial network, Leitner (2005) constructs a model where the success of one agent's investment in a project depends on the investments of other agents to which she is linked. Since endowments are randomly distributed across agents, any given agent may not have enough cash to make the necessary investment. In this case, agents may be willing to bail out other agents to prevent the collapse of the whole network. Leitner examines the design of optimal financial networks that minimise the trade-off between risk sharing and the potential for collapse. In a related paper, Kahn and Santos (2008) investigate whether banks choose the optimal degree of mutual insurance against liquidity shocks. They show that when there is a shortage of exogenously supplied liquidity, which can be supplemented by bank liquidity creation, banks generally fail to find the correct degree of interdependence. In aggregate, they become too risky.

Dasgupta (2004) also explores how linkages between banks, represented by crossholdings of deposits, can be a source of contagious breakdowns. The study examines how depositors who receive a private signal about banks' fundamentals may wish to withdraw their deposits if they believe that enough other depositors will do the same. To eliminate the multiplicity of equilibria the author uses the concept of global games. Dasgupta isolates a unique equilibrium, depending on the value of the fundamentals. In the same spirit, Brusco and Castiglionesi (2007) show that there is a positive probability of bankruptcy and propagation of crises across regions when banks keep interbank deposits and that they may engage in excessive risk taking if they are insufficiently capitalised.

Parallel to this literature, other researchers apply network techniques developed in mathematics and theoretical physics to study contagion. For instance, Eisenberg and Noe (2001) investigate default by firms that are part of a single clearing mechanism. First, the authors show the existence of a clearing payment vector that defines the level of connections between firms. Next, they develop an algorithm that allows them to evaluate the effects that small shocks have on the system. This algorithm produces a natural measure of systemic risk based on how many waves of defaults are required to induce a given firm in the system to fail. Similarly, Afonso and Shin (2008) use lattice-theoretic methods to study liquidity and systemic risk in high-value payment systems, such as those used for the settlement of accounts receivable and payable among industrial firms and interbank payment systems. Gai and Kapadia (2010) develop a model of contagion in financial networks using techniques similar to those in the epidemiological literature on the spread of disease in networks to assess the fragility of the financial system. As with Allen and Gale (2000), they find that greater connectivity reduces the likelihood of widespread default. However, shocks may have a significantly larger impact on the financial system when they occur.

The effects of informational contagion are investigated in a paper by Acharya and Yorulmazer (2008b). They show that banks engage in herding behaviour in order to minimise the information spillover from bad information about other banks on their own financing costs. In an otherwise standard banking model with two banks that have access to risky loans and get their funding from risk-averse depositors, the return on each bank's loans is determined by a common systematic component, say an industry effect, and an idiosyncratic component. The exposure of each bank's loan return to the systematic and idiosyncratic factors is common knowledge. The *ex post* performance of each bank's loan portfolio is also observed by the public. However, what is not observed by the economic agents is the exact realisation of the systematic and idiosyncratic factors. The banks can choose their lending structure, in particular whether they want to lend to similar industries, which implies a high level of interbank correlation. However, lending to similar industries has a negative impact on the lending margin because competition in the loan market increases.

Given this structure, Acharya and Yorulmazer (2008b) show that the cost of borrowing for a bank increases when depositors can observe bad news about another bank, since such news conveys bad information about the common factor. In particular, the increase in a bank's borrowing costs relative to a situation where one can observe good news about other banks is greater when bank loans have less commonality. Therefore, banks have incentives to herd and undertake similar investment in order to minimise the expected costs of borrowing. Only the erosion of lending margins that arises if banks lend into similar industries counteracts this herding force. However, as long as the competitive effect is not too large, banks will herd even if this leads to productive inefficiency due to underinvestment in profitable projects in other industries of the economy.

Since herding behaviour and contagion effects lead to a higher number of systemic banking crises, an interesting issue is how one should design the resolution of bank failures when many banks fail. This question is taken up by Acharya and Yorulmazer (2008a). They argue that during systemic banking crises, a private sector resolution for bank failures does no good since it leads to allocative inefficiency. The reason is 'cash-in-the-market' pricing for bank assets in liquidation. The acquisition of bank assets in liquidation is no problem if only a few banks fail since then these banks can be acquired by the surviving banks. However, in the case of a larger banking crisis with a high number of bank failures, the surviving banks typically have limited liquidity. This implies that they can acquire all the assets of the failed banks only at fire sale prices; there are too many banks to liquidate. However, the resulting 'cash-in-the-market' pricing attracts liquidity-endowed investors from outside the banking sector. Since these investors are quite often not the most efficient users of these assets, the wrong agents end up purchasing failed banks' assets.

Acharya and Yorulmazer (2008a) also analyse which type of regulatory intervention might be optimal for avoiding allocative inefficiencies. An *ex post* optimal bailout policy is typically suboptimal from an *ex ante* viewpoint since it induces banks to herd, as in Acharya and Yorulmazer (2008b). Anticipating such a bailout policy, banks have incentives to lend funds to similar industries or to bet on common risks in order to increase the likelihood of being bailed out. In turn, such behaviour increases the probability of experiencing systemic crises. However, there is a solution to this time-inconsistency problem. The government should provide liquidity by subsidising surviving banks for the purchase of failed banks. This liquidity provision policy gives banks incentives to differentiate *ex ante*, yet can be designed to be *ex post* equivalent to the bailout policy.

Allen and Carletti (2006) also rely on 'cash-in-the-market' pricing in their analysis of contagion effects. They are particularly interested in answering the question of whether the introduction of certain financial innovations, such as credit risk transfer instruments, creates inter linkages between different financial sectors that increase the danger of contagion. They focus on the structure of liquidity shocks that hit the banking sector in order to determine whether contagion results. When banks are not hit by idiosyncratic liquidity shocks, and therefore face a uniform demand for liquidity, they keep a sufficient amount of the short-term asset and do not need to raise additional liquidity in the market. In this case credit risk transfer is beneficial as it improves risk sharing across different sectors in the finance industry. However, when banks do face idiosyncratic shocks, a negative spillover effect can arise because of credit risk transfer.

There was some interesting empirical research on the functioning of interbank markets before the crisis. One of the first studies was conducted by Furfine (2001). By examining the pricing of interbank lending agreements, the paper investigates whether banks really monitor other banks. The main empirical finding is that the interest rate charged on federal funds transactions reflects, at least in part, the credit risk of the borrowing institution in the sense that borrowing institutions with higher profitability, higher capital ratios, and fewer problem loans pay lower rates. Furthermore, the size and relative importance of the trading institution has a negative impact on the interest rate charged for overnight borrowing. Both results suggest that banks can distinguish credit risk among peers and price it accordingly, therefore effectively monitoring other banks.

In a study conducted by Fecht, Nyborg and Rocholl (2011) which is based on 78 consecutive repo auctions by the Eurosystem between June 2000 and December 2001, the authors confirm the result that the price of liquidity systematically depends on bank characteristics such as size and liquidity position, and on market conditions. They find that a greater imbalance in liquidity positions across banks is associated with a rise in the price of liquidity. In particular, banks that are in need of liquidity are affected by the need to pay a higher price in times when there are overall greater imbalances in liquidity positions. This suggests that, even in relatively normal times in the interbank market, liquidity squeezes occur and needy banks are most affected by the potential for a squeeze. Imperfections in the market for liquidity appear to be an enduring and pertinent feature of modern financial systems.

Furfine (2002) considers the functioning of the interbank market in the second half of 1998 when Russia effectively defaulted on its sovereign debt and the hedge fund Long Term Capital Management needed to be rescued. Furfine shows that in this case the interbank market performed well and was not seriously disrupted by other market developments.

These empirical studies of liquidity in interbank markets suggest that the interbank market worked well, even in circumstances of stress. Unfortunately, this conclusion turned out to be incorrect in terms of its relevance for the current crisis.

There was substantial interest in looking for evidence of contagious failures of financial institutions before the crisis. Most of these papers use balance sheet information to estimate bilateral credit relationships. Based on these estimates, the stability of the banking system is tested by simulating the breakdown of a single bank. Upper and Worms (2004) use this methodology. They estimate a matrix of bilateral credit relationships for the German banking system and then simulate the failure of a single bank. They find broad scope for contagion. However, the prevailing financial safety net in Germany, that is, institutional guarantees for savings banks and cooperative banks, reduces the danger of contagion considerably. But even so, the failure of a single bank could lead to a breakdown of up to 15 per cent in terms of bank assets.

There are many other empirical studies that assess the danger of contagion in interbank markets (see Upper (2011) for a survey). For most countries, the simulations suggest that contagious defaults are unlikely, but at least in some countries they cannot be fully ruled out. If contagion does take place, then the simulations typically indicate a breakdown of a substantial part of the banking system.

With hindsight, the result that contagion was unlikely should have been treated with caution. First, since most of the studies focused on simulating the failure of a single bank for idiosyncratic reasons, this was not the scenario most relevant for supervisors. The analysis of the effects of shocks that affect several banks simultaneously is more relevant for understanding systemic risk and should have been studied more. Exceptions were the studies by Elsinger, Lehar and Summer (2006a, 2006b). The second problem was that the simulations conducted typically did not model the price effects of bank failures. However, as argued by Cifuentes, Ferrucci and Shin (2005) and others, these price effects are the main transmission mechanism for contagion.

2.2 Views after the crisis

The crisis led to an evolution in the financial stability literature. With a few exceptions, such as the run on Northern Rock, withdrawals from banks and the hoarding of cash were not significant problems. The widespread use of guarantees such as deposit insurance by governments prevented such runs. In fact, deposits turned out to be one of the most stable forms of finance.

Interbank markets, however, did not function well during the crisis. This turbulence in interbank markets has led to some very interesting recent contributions. These include Acharya, Gromb and Yorulmazer (2012), Freixas and Jorge (2008), Heider, Hoerova and Holthausen (2009), Diamond and Rajan (2011) and Acharya, Gale and Yorulmazer (2011).

Acharya *et al* (2012) model the interbank markets as being characterised by moral hazard, asymmetric information, and monopoly power in times of crisis. They show that in such a situation a bank with surplus liquidity has bargaining power vis-à-vis deficit banks which need liquidity to keep funding projects. Surplus banks may strategically provide insufficient lending in the interbank market in order to induce inefficient sales of bank-specific assets by the needy banks, which results in an inefficient allocation of resources. The role of the central bank is to provide an outside option to the deficit bank for acquiring the needed liquidity.

Freixas and Jorge (2008) examine how financial imperfections in the interbank market affect the monetary policy transmission mechanism. In their model, firms face liquidity shocks and rely on bank credit to raise external finance. Through this channel, firms' shocks result in a demand for credit and a liquidity shock for the banks. As a buffer against liquidity shocks, banks hold assets and liquid securities. Since banks hold different amounts of securities and face different liquidity shocks, there is a role for an interbank market to trade reserves. However, asymmetric information in the interbank market induces an equilibrium with quantity rationing in the bank loan market since the interbank market is unable to efficiently channel liquidity to solvent but illiquid banks. As a consequence, monetary transmission might have a strong effect because tightening monetary policy forces banks with less liquidity to cut down on their lending. In addition, liquidity reserves condition the banks' reaction to monetary policy.

In a similar vein, Heider *et al* (2009) analyse the functioning of interbank markets. They build a model in the spirit of Diamond and Dybvig (1983). As banks face individual liquidity shocks, there is a role for an interbank market in which banks with surplus liquidity can lend to those with a liquidity shortage. An interbank loan may not be repaid, however, because the long-term investment is risky, thus giving rise to counterparty risk. Asymmetric information about counterparty risk can elevate interbank market spreads and, in extreme situations, lead to a total breakdown of the interbank market. In the case of such severe adverse selection problems, either all the lenders in the market prefer to hoard liquidity despite high interest rates, or all the borrowers drop out because they find the interest rates too high.

Diamond and Rajan (2011) relate the seizing up of term credit to an overhang of illiquid securities. When banks have a significant quantity of assets with a limited set of potential buyers, shocks in future liquidity demands may trigger sales at fire sale prices. The prospect of a future fire sale of the bank's assets depresses their current value. In these conditions, banks prefer to hold onto the illiquid assets and risk a fire sale and insolvency than sell the asset and ensure their own stability in the future. This reflects that the states in which the depressed asset value recovers are precisely the states in which the bank survives. In turn, this creates high expected returns to holding cash or liquid securities across the financial system and an aversion to locking up money in term loans.

Acharya *et al* (2011) show that freezes in markets for rollover debt, such as asset-backed commercial paper, depend on how information about the quality of the asset is revealed. When there is a constant probability that 'bad news' is revealed each period, the value of the assets is high in the absence of bad news. By contrast, when there is a constant probability that 'good news' is revealed each period, the value of the assets is low in the absence of good news. In the latter scenario, the debt capacity of the assets is below the fundamental value and is decreasing in the liquidation cost and frequency of rollovers. In the limit, as the number of rollovers becomes unbounded, debt capacity goes to zero even for an arbitrarily small default risk.

A closely related literature focuses on the operation of markets when agents have liquidity shocks and trade in markets. The difference is that there are no banks or other intermediaries. A number of interesting results are derived. Huang and Wang (2009, 2010) show that purely idiosyncratic and non-fundamental shocks can cause market crashes if capital flow is costly. Agents trade to smooth out idiosyncratic shocks to their wealth. Since there is no aggregate uncertainty, their trades will be perfectly synchronised and matched, and there will be no need for liquidity if market presence is costless. In this case, the market-clearing price always reflects the fundamental value of the asset, and idiosyncratic shocks generate trading but have no impact on prices. In contrast, when market presence is costly, the need for liquidity arises endogenously and idiosyncratic shocks can affect prices via two channels: first trading becomes infrequent, which makes traders more risk averse; and second, the gains from trading for potential sellers are always larger than the gains from trading for potential buyers. The asymmetry in their appetite to trade leads to order imbalances in the form of excess supply, and the price has to decrease in response.

Two studies isolate illiquidity risk from other confounding effects. Morris and Shin (2009) define 'illiquidity risk' as the probability of a default due to a run when the institution would otherwise have been solvent. They show this differs from 'asset insolvency risk', which is the conditional probability of default due to a deterioration in asset quality in the absence of a run by short-term creditors, and 'total credit risk', which is the unconditional probability of default, due to either a (short-term) creditor run or (long-run) asset insolvency.

Brunnermeier and Pedersen (2009) distinguish between market liquidity and funding liquidity. Market liquidity reflects how difficult it is to raise money by selling an asset, instead of borrowing against it. Traders provide market liquidity, and their ability to do so depends on their availability of funding. Conversely, traders' funding, i.e. their capital and margin requirements, depends on the assets' market liquidity. They show that, under certain conditions, margins are destabilising and market liquidity and funding liquidity are mutually reinforcing, leading to liquidity spirals.

Another explanation for market freezes relies on asymmetric information. Bolton, Santos and Scheinkman (2011) provide a theory of liquidity provision with asymmetric information in which there is an adverse selection problem due to the superior information that intermediaries have about the assets they hold. When intermediaries sell assets they must do so at a discount that becomes greater the longer they hold an asset. If an intermediary is hit by a liquidity shock, the problem it faces is whether to sell its assets now at a discount or to try to ride out the crisis. In doing so, the intermediary runs the risk of having to sell at a greater discount if the crisis lasts longer than expected. In the *immediate trading equilibrium*, intermediaries sell assets immediately to ensure they have enough liquidity. In the *delayed trading equilibrium*, intermediaries try to ride out the crisis and only sell if they are forced to. For some parameter values only the immediate trading equilibrium exists, while for others both do, and in this case the delayed trading equilibrium is Pareto superior.

One important empirical question that arises out of all these theoretical studies is how the liquidity of the financial system, and in particular that of banks, should be measured? Berger and Bouwman (2009) have suggested a method for measuring liquidity created by the banking system and have applied this to the case of the United States. They start by classifying all bank liabilities together with off-balance sheet items as liquid, semi-liquid and illiquid. By assessing weights for these three categories, they calculate the amount of liquidity created by the banking system. They show that liquidity increased every year between 1993 and 2003, almost doubling during the period. By applying this measure, similar results are found by Rauch *et al* (2010) for the German savings bank sector.

In a subsequent paper, Berger and Bouwman (2013) use their measure of liquidity to examine the relationship between liquidity and crises by focusing on the sample period from 1984 until 2008. They find that banking crises were preceded by abnormally high liquidity creation. Hence, it is important to understand how liquidity is created and how this relates to crises.

3. The Funding of Firms

3.1 Views before the crisis

Liquidity problems not only affect financial institutions but also have a significant impact on firms. They can lead to firms cutting back their investments and operations and as a result there can be significant macroeconomic impacts. An important early contribution that analyses firms' liquidity risk management is Holmström and Tirole (1998). The authors consider the demand for and supply of liquid assets based on the insight from modern corporate finance that, in general, some part of a firm's income stream cannot be pledged to investors. Several reasons can be given for why part of the income from investment would be non-pledgeable; for instance, it might be due to the missing participation of investors in certain markets, or due to imperfect information which reduces the potential set of financial claims. However, one key implication of non-pledgeability is that firms as well as consumers can rely on liquidating only part of their wealth whenever they need funds. Hence, to cope with negative financial shocks, they must hoard liquid assets or contract in other ways for the provision of liquidity. Accordingly, they are willing to pay a premium for financial services. Since the supply of liquid assets is constrained by the fact that only part of the return from productive assets can be pledged, non-pledgeability also reduces the amount of wealth in the economy which investors could use for the future financing of firms. In sum, non-pledgeability gives rise to a demand for stores of value across periods, as well as across future states of nature.

Based on this framework, Holmström and Tirole investigate three ways by which the private sector can meet future liquidity needs on its own: by issuing new claims; by obtaining a credit line from a financial intermediary; and by holding claims on other firms. They show that the private sector provides enough liquidity if the corporate sector is a net borrower and there is no aggregate shock. However, even without aggregate uncertainty, financial intermediaries that hoard financial assets and allocate liquidity to firms in need are required to support such a second-best plan. They have to coordinate the use of scarce liquidity by creating a sufficiently rich set of contingent claims, a function which a stock and bond market in general cannot fulfil. The reason is that, because of limited commitment possibilities, there is an insufficiently rich set of financial instruments and therefore liquidity is wasted. If all firms are hit by the same macroeconomic shock, or more generally if there is sufficient aggregate uncertainty, the private sector cannot provide enough liquidity on its own.

Holmström and Tirole show that in such a situation financial instruments that are originated outside the private sector can improve productive efficiency by facilitating access to liquidity and lowering its cost. They argue that a government can provide these instruments by issuing bonds that commit future consumer income. Since the government has the power to enforce tax payments, it can commit funds on behalf of consumers who are unable to commit their future endowments, unless these endowments are backed by marketable assets. Through its taxation power, a government can issue securities at a premium, thereby creating liquidity for the corporate sector. The authors show that the government should loosen liquidity when the economy is hit by a high negative aggregate liquidity shock, and should tighten liquidity when the shock is low.

The setup in Holmström and Tirole (1998) has proved to be extremely useful for analysing a broad range of questions. For instance, Holmström and Tirole (2011) study how such a theory can explain the pricing of assets, the role of liquidity management, and real investment. They also consider how this theory relates to some classic issues in macroeconomics and international finance, such as the question why international markets cannot meet a country's liquidity needs even though there are more than enough financial instruments for saving and insurance, and that of why inefficiencies arise when firms do not coordinate either the use or the acquisition of international liquidity.

Gorton and Huang (2004) also consider the situation where firms face liquidity risk. However, they use a framework that is quite different from that of Holmström and Tirole (1998) and also apply a different notion of liquidity. In their general equilibrium model, the focus is on the transferability of distressed projects, which is the motivation for immediate selling and borrowing. In Holmström and Tirole (1998), and many other papers such as Bolton *et al* (2011), and Diamond and Rajan (2001, 2006), a liquidity shock is typically modelled as a sudden need for funds. Here, by contrast, a shock means that long-term projects have a low value, i.e. are distressed, which may induce owners of these projects to engage in value-destroying activities. In other words, there is moral hazard. Such a negative shock to the value of assets in the hands of an entrepreneur creates a potential need to sell the control rights to the project. Only a recapitalisation of such a project by selling it in a 'liquidation' market to agents with enough available liquid assets can lead to a situation where the new owners will not engage in value-destroying activities. In anticipation of these opportunities in the market for liquidation, entrepreneurs choose at the first date whether to be buyers or sellers in the secondary market. As buyers, they invest at the first date in short-term projects, with the only purpose of obtaining liquid assets to possibly buy a distressed long-term project at a later date. As sellers, they invest in a risky long-term project that is socially more efficient, but illiquid. In that way, the supply of liquidity is endogenised.

Gorton and Huang argue, however, that the private provision of liquidity is typically costly for a society. It would be better if, instead of projects being sold in the liquidation market, original lenders were willing to forgive the debt of borrowers with low-value projects. But, debt forgiveness is not always in the interest of lenders. If it is not in their interest, liquidity will, even though socially inefficient, be hoarded because this is the only way to recapitalise projects. Therefore, they suggest one should analyse whether the government could improve welfare by supplying liquidity. Similarly to Holmström and Tirole (1998), the authors show that the government can use its taxation power on the owners of illiquid high-value projects to recapitalise owners of low-value projects. The state can issue securities backed by tax revenue collected from these entrepreneurs at a later time, to subsidise low-value projects. By extending this analysis to consider possible systemic risk in the banking system, the authors investigate whether bank bailouts are efficient. Building on the same argument, they provide conditions under which the government can improve welfare by bailing out banks. This is the case if, when banks suffer a negative shock to their capital, they are subject to moral hazard by not being interested in recapitalising their borrowers' projects. Anticipating this, too much liquidity will be privately supplied which reduces welfare.

The papers by Holmström and Tirole (1998) and Gorton and Huang (2004) complement each other. While the first analyses why it is important to have a stock of government-supplied liquidity in the economy and why this liquidity should be actively managed, Gorton and Huang in addition offer a rationale for bank bailouts by the government. They show that this type of intervention can improve efficiency whenever there is the potential problem of banks engaging in moral hazard.

A related paper is Kiyotaki and Moore (2005) who examine the interaction between liquidity, asset prices, and aggregate economic activity. They investigate in a general equilibrium framework the role of liquid assets for resource allocation. Liquid assets, which they also call monetary assets, are defined as any asset class that can be readily sold in the market and, therefore, serves as a medium of exchange since it circulates among many agents as a means of short-term saving. This allows Kiyotaki and Moore to analyse the conditions under which the circulation of liquid assets is essential for the smooth running of the economy. The terms liquid assets and monetary assets will be used interchangeably since all assets are real and not denominated in cash.

Output is produced from two types of assets, capital and land, with the usual assumption that the capital stock can be built up through investment, whereas the supply of land is fixed. They, however, depart from the usual representative agent framework by assuming that at each point in time only a fraction of agents has access to productive investment opportunities, even though agents are equally likely to find investment opportunities in the future. They also assume incomplete markets in the sense that the agents have no possibilities to buy *ex ante* insurance contingent on the arrival of investment opportunities. Furthermore, the capital stock is an asset with limited liquidity since, at the time of investment, agents can sell only a fraction of their capital stock. This type of financial friction is in its impact similar to the non-pledgeability assumption in Holmström and Tirole (1998) or the limited commitment assumption in Diamond and Rajan (2001). Therefore, investing agents may face binding liquidity constraints. Only land is a liquid or monetary asset in the sense that agents can pledge the full value of their land holdings at the time of investment.

They show that in such an economy the circulation of monetary assets is essential for resource allocation since only this allows a smooth transfer of purchasing power from those without an investment opportunity to those with such an opportunity. Second, this circulation of liquid assets is even more important if each agent rarely has an investment opportunity, if investing agents can only pledge a small fraction of their capital, and if the income share of land is small relative to capital.

The model delivers an explanation of the liquidity premium that liquid assets typically command. If investing agents anticipate liquidity constraints at the time of investment, they have strong incentives to hold the liquid assets in their portfolios, even if the return on the liquid assets is lower than the time preference rate. Furthermore, the model generates an interesting feedback mechanism between asset prices and aggregate economic activity. As in the standard framework, higher future expected dividends translate into higher asset prices. However, here, higher asset prices also lead to higher liquidity, which eases the transfer of resources from savers to investors, and encourages aggregate investment and production. Thus, the model can explain the interaction between asset prices, liquidity, and economic activity. In particular, it delivers an account of the large fluctuations in asset prices and aggregate output that are typically observable in financial crisis, and in 'normal times' though to a smaller extent. However, since fiat money has no particular role in the framework, it is, at least in the specific setting developed in Kiyotaki and Moore (2005), not possible to analyse the impact of monetary shocks or monetary instruments. Kiyotaki and Moore (2008) provide an interesting extension of the model, where they study how aggregate production and asset prices fluctuate with shocks to productivity and liquidity. Thereby, they also examine the role of government policy, which basically through open market operations, changes the mix of assets held by the private sector.

An interesting example of inefficiencies created by the working of the financial system is analysed in the paper by Lorenzoni (2008) which raises the question of why inefficient credit booms can emerge. Financial frictions, experienced by both borrowers (entrepreneurs) and lenders (consumers), are the fundamental source of inefficiency. Both have limited ability to commit to future repayments which implies that entrepreneurs face (external) financial constraints and consumers cannot fully insure entrepreneurs against aggregate liquidity shocks *ex ante*, as in Holmström and Tirole (1998). Lorenzoni motivates his analysis about the (in)efficiency of credit booms with the observation that, in particular in the last two decades, many developed and emerging countries have experienced episodes of credit expansion which were typically followed by a financial crisis with a collapse in asset prices. He analyses the conditions under which a credit boom arises, why the credit boom may be inefficient from an *ex ante* perspective, and whether any intervention is warranted. He shows that excessive borrowing activity by entrepreneurs can arise in equilibrium. This, in turn, leads to an excessive contraction in investment activity and asset prices if the crisis takes place, even though all entrepreneurs are rational and correctly perceive the risks and rewards associated with different financial decisions. Key to the result is a pecuniary externality which arises from the combination of the financial constraints mentioned above with a competitive market for real assets.

The model uses a three-period framework. In the first period, entrepreneurs have to borrow funds for productive investment. In the second period, investment returns are subject to an aggregate shock. When a bad shock hits, entrepreneurs face operational losses, which means that they have to sell part of their assets to finance these losses. Assets are sold in a competitive market where they are bought by a traditional sector, i.e. other less productive entrepreneurs. In essence, this setup is closely related to Gorton and Huang (2004). In the third period, consumption takes place and capital fully depreciates.

Although entrepreneurs have access to state-contingent contracts, in the sense that they can *ex ante* decide how much to borrow in the first period and how much to repay in different states of the world in the following periods, an inefficiency will arise. Basically, entrepreneurs face the following trade-off: if they invest more in the first period, they can earn higher returns if the good shock is realised. However, they incur larger losses if the bad shock hits. Even with these state-contingent contracts and despite being fully rational, the atomistic entrepreneurs do not take into account the general equilibrium effect of asset sales on asset prices. They do not internalise this pecuniary externality. Therefore, from a social efficiency viewpoint, they invest too much. Accordingly, a social planner should reduce aggregate investment *ex ante*, because this reduces the amount of asset sales in the bad state. This has a positive effect on asset prices and leads to a reallocation of funds to more productive uses, i.e. from the traditional sector to the entrepreneurial sector, which due to the presence of financial frictions leads to a welfare gain. In essence, the paper formalises the notion that credit booms might be inefficient because they lead to higher systemic risk in the economy. Here, systemic risk increases because more individual borrowing by entrepreneurs creates a pecuniary externality which results in higher fluctuations of asset prices. Again, we have a general equilibrium feedback mechanism between financial distress and asset prices that drives the results.

3.2 Views after the crisis

Aggressive monetary policy in most countries meant that, with some exceptions, firms (particularly large corporations) did not face funding problems for a protracted period. This was in contrast to banks and other financial institutions that faced major problems for protracted periods. There were breakdowns in some corporate funding markets that overlapped with those for financial institutions, such as commercial paper markets.

However, the analysis of Holmström and Tirole (1998) and Gorton and Huang (2004) were relevant to the crisis in terms of the shortage of risk-free assets. Gorton (2008) argues that there was a large demand for risk-free assets that led to the creation of securitised mortgages. Although these were rated as very safe by the rating agencies, they in fact turned out to be risky and this contributed greatly to the severity of the crisis.

4. Real Estate Markets

4.1 Views before the crisis

There is extensive evidence that the most important cause of banking crises is real estate booms and busts. Herring and Wachter (1999) document a wide range of boom and bust real estate cycles and their effects on banks. These episodes include Boston in the 1970s and 1980s, Sweden in the 1980s and 1990s, the Japanese bubble of the same period, and Thailand in the 1990s.

Reinhart and Rogoff (2009, Chapter 13) summarise a broad range of episodes where real estate played an important role in causing banking crises. As shown in Table 1, these include the 'Big Five' in advanced economies (Spain in the 1970s, Norway in the 1980s, Sweden, Finland and Japan in the 1990s) and the 'Big Six' in the Asian Crisis in 1997 (Hong Kong, Indonesia, Malaysia, the Philippines, South Korea and Thailand). Other examples from emerging countries are Colombia in 1998 and Argentina in 2001. Two interesting historical episodes are Norway in 1898 and the United States in the Great Depression. In Chapter 16 they provide evidence of the important role real estate played in many countries during the Great Depression.

Table 1: Real Housing Price Cycles and Banking Crises
From Reinhart and Rogoff (2009)

Economy	Crisis date	Peak	Trough	Duration of downturn	Magnitude of decline
					Per cent
Advanced economies: The Big Five					
Finland	1991	1989:Q2	1995:Q4	6 years	–50.4
Japan	1992	1991:Q1	Ongoing	Ongoing	–40.2
Norway	1987	1987:Q2	1993:Q1	5 years	–41.5
Spain	1977	1978	1982	4 years	–33.3
Sweden	1991	1990:Q2	1994:Q4	4 years	–31.7
Asian crisis: The Big Six					
Hong Kong	1997	1997:Q2	2003:Q2	6 years	–58.9
Indonesia	1997	1994:Q1	1991:Q1	5 years	–49.9
Malaysia	1997	1996	1999	3 years	–19.0
Philippines	1997	1997:Q1	2004:Q3	7 years	–53.0
South Korea	1997		2001:Q2	4 years	–20.4
Thailand	1997	1995:Q3	1994:Q4	4 years	–19.9
Other emerging economies					
Argentina	2001	1999	2003	4 years	–25.5
Colombia	1998	1997:Q1	2003:Q2	6 years	–51.2
Historical episodes					
Norway	1898	1899	1905	6 years	–25.5
US	1929	1925	1932	7 years	–12.6

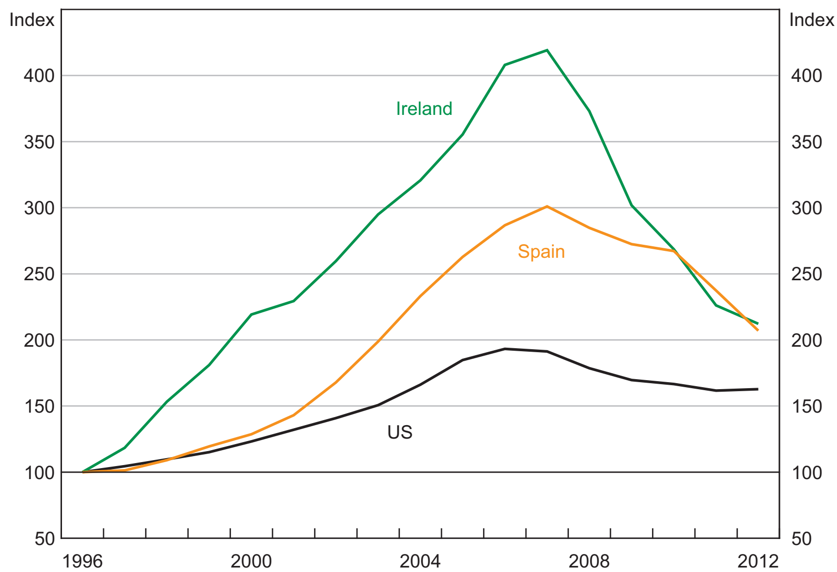
Sources: Bank for International Settlements; individual economy sources as described in Reinhart and Rogoff (2009, Data Appendixes)

Finally, Crowe *et al* (2011, Text Table 1, p 5) give data on the relationship between real estate boom and bust cycles, banking crises, credit crunches and macroeconomic performance, using a sample of 40 countries. For example, more than two-thirds of the 46 systemic banking crises for which house price data are available were preceded by boom and bust episodes. In addition, 35 out of 51 boom and bust episodes were followed by a banking crisis.

Real estate clearly played an important role in the current crisis. Figure 1 plots nominal housing prices in Ireland, Spain and the United States. It can be seen that the boom and bust in Ireland was particularly large and was the cause of Ireland's severe banking crisis. Because the state guaranteed the banks' debt, the boom-bust cycle has also caused a sovereign debt crisis. This led to the bail-out by other euro area and European Union governments. Spain also had a large run up in real estate prices. So far they have not fallen as much as in Ireland. However, as Taylor (2008) points out, Spain had the biggest housing boom as measured by the change in housing investment as a share of GDP. This is why Spain's unemployment rate has been so high during the bust phase of the cycle.

Figure 1: Nominal Housing Prices

1996 = 100



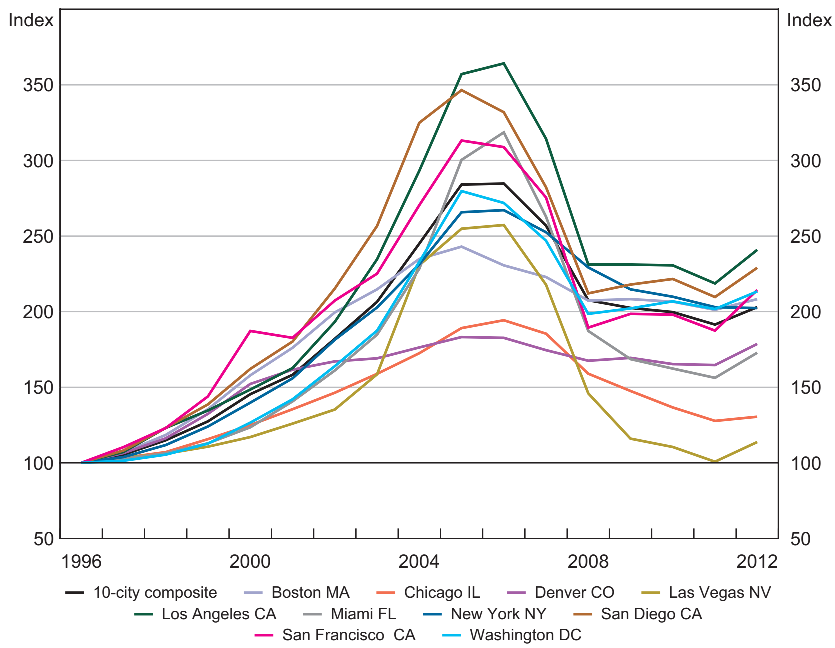
Sources: CEIC Data; European Central Bank

The plots in Figure 1 suggest that there might be positive serial correlation in housing returns. Case and Shiller (1989), Englund, Quigley and Redfearn (1998) and Glaeser and Gyourko (2007) have investigated this issue using a range of different datasets. They do indeed find evidence of positive serial correlation. For example, Glaeser and Gyourko (2007) find that a $1 increase in real estate prices in one year will on average be followed by a $0.71 increase the following year. Thus, once a real estate boom has started, it is likely that it will persist for some time. Similarly for a bust; once real estate prices have started to fall, this is likely to continue. This feature of real estate prices is very different from stock prices, where there is extensive evidence that stock returns are (at least to a first approximation) a random walk. The serial correlation in real estate returns is an important phenomenon that is not well understood.

A striking feature of Figure 1 is that the US boom and bust cycle was much less extreme than that in Ireland and Spain. However, this is misleading because the figures are for the country as a whole. There was very wide variation in experiences in different parts of the country. Figure 2 shows the experiences of the ten cities that make up the S&P/Case-Shiller 10-city index. Two things stand out. The first is that from the mid 1990s until the early 2000s, prices in all ten cities move together. But for the next few years the cities had widely different experiences. Miami and Los Angeles had massive booms and busts, while Denver had a relatively small change in prices. The other cities were somewhere in between. However, in all these cases, interest rates and many other features of the credit market were common. It is not well understood why the experiences were so similar and then so different.

Figure 2: Nominal Housing Prices in Different US Cities

S&P/Case-Shiller 10-city index, 1996=100, seasonally adjusted



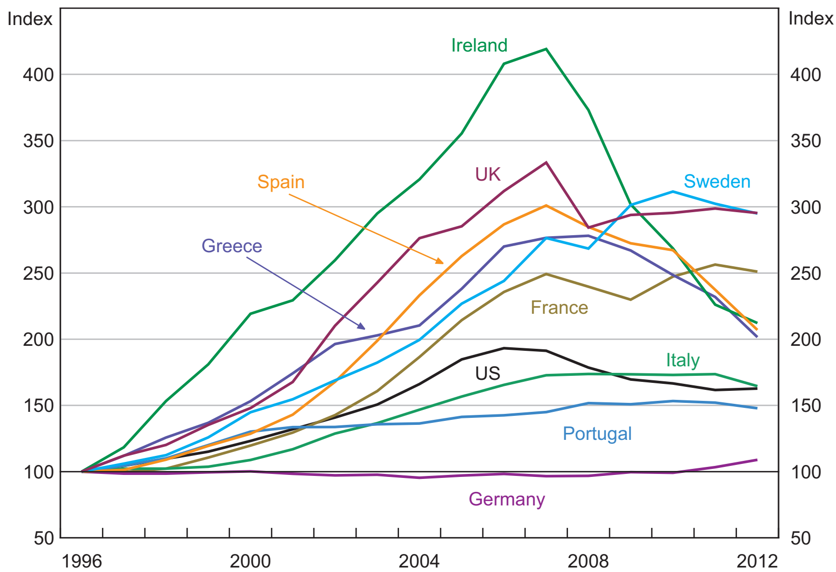
Source: Bloomberg

One of the major debates about the boom and bust episodes in the current crisis is the extent to which the real estate bubbles in these countries were the result of loose monetary policy and global imbalances that led to excessive credit availability. Central banks, in particular the Federal Reserve in the United States, set very low interest rates during the early 2000s to avoid a recession after the bursting of the technology bubble in 2000 and the 9/11 terrorist attacks in

2001. As argued by Taylor (2008), these levels of interest rates were much lower than in previous US recessions relative to the economic indicators at the time captured by the 'Taylor rule'.

Although the ECB did not set absolute rates as low as those set by the Federal Reserve, the different economies had very different conditions. As Figure 1 shows, Spain and Ireland had very large increases in property prices. For these economies the ECB's policy was very loose. Figure 3 shows the wide disparity of movements in property prices in Europe. While Ireland and Spain had big run-ups and collapses, other countries like the United Kingdom and Sweden had large run-ups but did not experience big collapses. By contrast, France and Germany, which are quite similar in terms of their industrial structure, and are both members of the euro area, had very different experiences in terms of property prices. This underlines our lack of knowledge concerning the determinants of real estate prices.

Figure 3: Nominal Housing Prices in the US and Selected European Countries
1996 = 100



Sources: CEIC Data; European Central Bank

Taylor's position has been quite controversial. For example, Bernanke (2010) has argued that the Taylor rule is sensitive to the choice of inflation measure and to whether actual or forecast inflation and output gaps are used. Once changes in these measures are introduced, it is no longer clear whether interest rates were unusually low given the state of the economy, or whether house prices were unusually high given interest rates and the state of the economy. Bernanke concludes that Taylor's claim is not persuasive enough. He suggests that what seems to have played a crucial role in setting the stage for the crisis is financial innovation in the form of mortgage contracts and securitisation. Rather than interest rates being set too low, the implications of financial innovation for monetary policy transmission were not understood by monetary policymakers. This failure, together with weak financial regulation and supervision, set the stage for the crisis.

As Allen and Gale (2000, 2003, 2007) have argued, asset price bubbles are also caused by growth in credit. During the recent crisis, credit expanded rapidly in the countries with low interest rates that were partly the results of global imbalances. In particular, several Asian countries started accumulating large amounts of reserves in the late 1990s, which lowered interest rates and helped fuel the bubble in asset prices. It was the bursting of this bubble that started the crisis; in the summer of 2007, the fall in property prices triggered a fall in price and downgrading of securitised mortgages.

4.2 Views after the crisis

Before the crisis, mortgages in the United States were securitised by both public firms such as Fannie Mae and Freddie Mac, and private firms such as investment banks. Once the crisis started, the private market disappeared and since then it has not reappeared. The only sector that remains in the United States is the public one. In the long run, one of the major issues is how the private sector can be restored.

5. The Role of Central Banks in Funding Markets

5.1 Views before the crisis

5.1.1 The central bank as lender of last resort

At least since the work of Bagehot and the 19th and 20th century interventions by the Bank of England, it has been recognised that central banks have a crucial role to play in the prevention and management of financial crises. In his influential book, *Lombard Street*, Bagehot (1873) laid out his famous principles for how a central bank should lend to banks during a crisis.

- Lend freely at a high rate of interest relative to the pre-crisis period but only to solvent but illiquid borrowers with good collateral (i.e. any assets normally accepted by the central bank).
- The assets should be valued at between panic and pre-panic prices.
- Institutions without collateral should be allowed to fail.

Despite being written over 140 years ago, these principles are still widely quoted and used as the foundation for many central bank policies. However, their validity in terms of modern financial economics has only been considered in a few papers.

Rochet and Vives (2004) is one of the few papers that has recently examined the Bagehot principles. In particular, the authors focus on Bagehot's assertion that the LOLR should lend to any solvent but illiquid banks. In the past, several authors, such as Goodfriend and King (1988), have dismissed this view as obsolete since in modern interbank markets it cannot be the case that a solvent bank is illiquid. Of course, in light of the recent crisis, one can have serious doubts as to whether such an argument is true. For that reason, it is even more interesting that Rochet and Vives provides a theoretical foundation supporting Bagehot's doctrine regarding this dimension. An important problem in the banking literature in the spirit of Bryant (1980) and Diamond and

Dybvig (1983) is that the fragility of banks depends crucially on possible coordination failures between depositors that can trigger bank runs. Given the assumption of first-come, first-served, and costly liquidation of long-term assets, there are multiple equilibria, which makes it hard to base any policy recommendations on such a framework. Using the global games approach, Rochet and Vives develop a theory which does not rely on multiple equilibria. Instead, their model produces a unique Bayesian equilibrium that is characterised by a positive probability that a solvent bank cannot get enough liquidity assistance in the market. Hence, in this respect the Bagehot doctrine still has a solid theoretical foundation.

One of the criticisms of the kind of LOLR policy advocated by Bagehot is that it creates a moral hazard problem in the sense of increasing the incentives for banks to take more risk. Repullo (2005) investigates this claim about LOLR lending. By modelling the strategic interaction between a bank and a LOLR, he shows that in general this proposition is not true. He assumes a bank which is funded with insured deposits and equity capital, is subject to capital requirements, and can invest, like in a Diamond-Dybvig framework, in two assets: a safe liquid asset and an illiquid asset, the risk of which will be privately chosen by the bank. Since deposits are randomly withdrawn, the bank is subject to liquidity shocks. Because the bank optimally will not invest all its endowment in liquidity, in case of a large negative withdrawal shock it has to rely on emergency lending from a LOLR to avoid being forced into liquidation. In this setting, Repullo shows that in equilibrium the bank chooses a risk level that is decreasing in the capital requirement and increasing in the penalty rate charged by the LOLR. However, in the case where the LOLR does not charge the penalty rate, there is an irrelevance result regarding the risk choice. Irrespective of the existence of a LOLR, the bank chooses the same level of risk, but the liquidity buffer chosen is lower when a LOLR exists.

5.1.2 Money creation and financial stability

Fiat money does not play a role in most models of banking crises. Typically, banks contract with depositors in real terms, and if government-injected liquidity is essential in preventing a crisis or alleviating an aggregate liquidity shortage, it will be done using appropriate financial and fiscal instruments that have effects in real terms. However, it is apparent from many crisis experiences in the past that monetary policy also seems to be important in crisis situations. A number of papers before the crisis considered the relationship between money and financial stability.

Much of this early literature seeks to explain historical crises that occurred at a time when fiat currency played an important role in the financial system. An early contribution is Champ, Smith and Williamson (1996). They address the issue of why Canada had no banking crises in the late 19th and early 20th centuries while the United States had many. Their explanation is that Canada allowed the amount of money in circulation to expand to meet demand during harvest time while this could not happen in the US financial system. The effect of this difference was that in Canada liquidity shocks could be easily absorbed but in the United States they led to banking panics. Since currency played an important role during this period, the authors use an overlapping generations model with two-period lived consumers to justify the use of currency. The consumers live in two different locations. Instead of random preference shocks as in Diamond and Dybvig (1983), consumers are subject to relocation shocks. Each period a random proportion of young consumers in each location is forced to move to the other location. These shocks are symmetric so that the population in each place remains constant. Banks make risk-free loans, hold reserves of currency, issue bank notes, and write deposit contracts that are contingent on the proportion of the consumers that relocate. When young consumers relocate they can transport currency or the notes issued by the banks with them but nothing else. The authors show that if the banks are allowed to vary their issuance of notes to accommodate different levels of relocation shocks then there exists a stationary Pareto-optimal equilibrium. In this equilibrium, currency and banknotes are perfect substitutes and the nominal interest rate is zero. However, if the banknote issuance is fixed such that the random relocation demand cannot be accommodated, there will be a banking crisis if the shock is large enough to exhaust the banks' currency reserves. The authors interpret these two possibilities as being consistent with the Canadian and US experiences from 1880–1910.

Antinolfi, Huybens and Keister (2001) build on the model of Champ *et al* (1996) by replacing the private issue of banknotes with a LOLR that is willing to lend freely at a zero nominal interest rate. A stationary Pareto-optimal equilibrium again exists but in addition there is a continuum of non-optimal inflationary equilibria. Antinolfi, Huybens and Keister are able to show that these can be eliminated if the LOLR places an appropriately chosen upper bound on the amount that each individual bank can borrow or is willing to lend freely at a zero real interest rate.

Smith (2002) considers a similar model with two-period lived overlapping generations, where spatial separation and random relocation introduces a role for money and banks. He shows that the lower the inflation rate and nominal interest rate, the lower is the probability of a banking crisis. Reducing the inflation rate to zero in line with the Friedman rule eliminates banking crises. However, this is inefficient as it leads banks to hold excessive cash reserves at the expense of investment in higher yielding assets.

Cooper and Corbae (2002) consider a model with increasing returns to scale in the intermediation process between savers and entrepreneurs. This leads to multiple equilibria that are interpreted as different levels of confidence. A calibrated version of the model with low confidence levels is able to match many features of the Great Depression.

As discussed above, Diamond and Rajan (2001) develop a model where banks have special skills to ensure that loans are repaid. By issuing real demand deposits, banks can pre-commit to recoup their loans. This allows long-term projects to be funded and depositors to consume when they have liquidity needs. However, this arrangement leads to the possibility of a liquidity shortage in which banks curtail credit when there is a real shock. Diamond and Rajan (2006) introduce money and nominal deposit contracts into this model to investigate whether monetary policy can help alleviate this problem. They assume there are two sources of value for money. The first arises from the fact that money can be used to pay taxes (the fiscal value). The second is that money facilitates transactions (the transactions demand). They show that the use of money can improve risk sharing since price adjustments introduce a form of state contingency to contracts. However, this is not the only effect. Variations in the transaction value of money can lead to bank failures. Monetary intervention can help to ease this problem. If the central bank buys bonds with money, this changes liquidity conditions in the market and allows banks to fund more long-term projects than would be possible in the absence of intervention.

Allen and Gale (1998) develop a model of banking crises caused by asset return uncertainty with three dates, early and late consumers as in Diamond and Dybvig (1983), and initially, real contracts. Building on the empirical work of Gorton (1988), it is assumed that at the intermediate date investors receive a signal concerning the return on the banks' long-term assets. If the signal indicates returns are sufficiently low, the late consumers will withdraw their deposits along with the early consumers and there will be a banking crisis. Allen and Gale go on to show that if contracts are written in nominal terms and a central bank can supply money to commercial banks, the incentive-efficient allocation can be implemented: the central bank gives money to the banks and they then pay this out to depositors. The early depositors use their money to buy goods from early-withdrawing late consumers who then hold money until the final date. Variations in the price level allow risk sharing.

Skeie (2008) develops a standard banking model with nominal contracts and inside money where depositors are subject to preference shocks in the usual way. There is no aggregate liquidity risk or return uncertainty. In contrast to Diamond and Dybvig (1983), Skeie shows that there is a unique equilibrium and it is efficient. If deposits are withdrawn by late consumers at the intermediate date, the price of the consumption good adjusts and this discourages such withdrawals. In order for there to be runs on banks there must be some other friction, such as problems in the interbank market.

5.2 Views after the crisis

The dramatic interventions undertaken by many central banks since the onset of the crisis has led to many contributions trying to understand their role in funding markets. A number of studies focus on their intervention in interbank markets.

Allen, Carletti and Gale (2009) show that the interbank market is characterised by excessive price volatility when there are insufficient opportunities for banks to hedge aggregate and idiosyncratic liquidity shocks. They analyse how the central bank should intervene to restore efficiency. By using open market operations to fix the short-term interest rate, the central bank can prevent price volatility and implement the constrained efficient solution. Thus, the central bank effectively completes the market, a result in line with the argument of Goodfriend and King (1988) that open market operations are sufficient to address pure liquidity risk in the interbank markets. Interestingly, one implication of the model is that situations where banks stop trading with each other can be a feature of the constrained efficient solution implemented by central bank policy if aggregate uncertainty is high. Banks may hoard liquidity because they may need it to meet high aggregate demand. When aggregate demand is low, however, they have enough liquidity to meet idiosyncratic shocks and accordingly do not need the interbank market. As a result the volume in the market falls to zero, but there is no need for central banks to intervene since the freeze is consistent with constrained efficiency.

Freixas, Martin and Skeie (2011) develop a model with aggregate liquidity risk, which like Allen, Carletti *et al* (2009) also has idiosyncratic liquidity shocks to banks. They suggest that inducing low interbank market rates in states of financial disruptions is an optimal policy response of the central bank. As they argue, a primary role for banks in the presence of incomplete markets is to provide better risk-sharing possibilities and more liquidity than markets. Yet during financial disruption, the banks themselves face considerable uncertainty regarding their own idiosyncratic liquidity needs. Hence, they may have large borrowing needs in the interbank market. They show that an interbank market can achieve the optimal allocation, which implies efficient risk sharing to consumers and effective insurance for banks against idiosyncratic liquidity shocks. In the optimum, however, the interest rate in this market must be state-contingent and low in states of financial disruption. This suggests a role for the central bank, which in their model can implement the efficient allocation by setting the interest rates in the interbank market.

The main part of Freixas *et al* (2011) presents a real analysis where they show that there can be multiple equilbria, but that the central bank can determine the interest rate that implements the equilibrium with the efficient allocation. In an appendix, they show that money can be introduced along the lines of Skeie (2008) and the same results hold.

Allen, Carletti and Gale (forthcoming) also focus on inside money. At the initial date the central bank makes an intraday loan to the banks. Money is loaned to the firms that produce the goods, to fund the purchase and the consumers' endowment. The payment from the firms is made to the consumers' deposit accounts and the bank uses this money to repay its loan to the central bank. At the intermediate and final dates, the reverse process occurs: banks use the intraday loan from the central bank to repay depositors who use the funds to buy goods from firms. The firms use the money to repay their loans to the bank and the banks in turn repay the central bank. All money balances are held within the banking system in deposit accounts. This feature is important, since it means that, in contrast to the papers using the Champ *et al* (1996) model, the central bank is free to set the nominal interest rate to control the level of inflation. In practice, fiat currency is used relatively little in modern financial systems. It could be added to the model if it was recognised that for some transactions it is more convenient than debit or credit cards.

In contrast to the previous literature, Allen *et al* (forthcoming) consider a wide range of risks. The banks' long-term assets, which can be thought of as loans, are subject to aggregate uncertainty. There is aggregate risk in liquidity shocks to consumers. In addition, there are also idiosyncratic liquidity shocks to individual banks as in Bhattacharya and Gale (1987). In contrast to the Champ *et al* model, where contracts are state-contingent, deposit contracts are assumed to be fixed in nominal terms. In spite of the multiplicity of risks the authors are able to show that provided the central bank runs an accommodative policy in terms of granting intraday loans, the first-best efficient allocation will result from the decentralised banking system described. Moreover, this allocation is unique. In the efficient equilibrium that we characterise there are no banking crises. Banks never fail, no matter how low asset returns fall, or how large are the aggregate liquidity shocks. The central bank always provides enough money to the banks to allow them to repay their depositors. The central bank can also control the expected level of inflation between the initial date and the first date and the actual level of inflation between the intermediate and final dates.

Central banks adopted many unconventional policies during the crisis. These include direct intervention in some markets like the commercial paper market. Other interventions involved the purchase of non-government securities. Quantitative easing policies involving the purchase of large quantities of government securities have also been widely adopted. An important issue is the extent to which these policies have distorted asset prices. This is another very contentious area. A key remaining issue is the ease with which central banks will exit from these policies.

6. Concluding Remarks

There remains one other important set of funding markets that have operated imperfectly during the crisis. These are government debt markets. There is a large literature on sovereign default. However, it was widely assumed that this was an emerging country problem. The default of Greece in March 2012 showed that this assumption was incorrect. The possibility of sovereign default has had a significant effect on some countries' funding opportunities, particularly those on the periphery of the euro area. This is a very large topic and raises rather different issues than those considered here, so we do not attempt to discuss funding of governments here.

References

Acharya VV, D Gale and T Yorulmazer (2011), 'Rollover Risk and Market Freezes', *The Journal of Finance*, 66(4), pp 1177–1209.

Acharya VV, D Gromb and T Yorulmazer (2012), 'Imperfect Competition in the Interbank Market for Liquidity as a Rationale for Central Banking', *American Economic Journal: Macroeconomics*, 4(2), pp 184–217.

Acharya VV and T Yorulmazer (2008a), 'Cash-In-The-Market Pricing and Optimal Resolution of Bank Failures', *The Review of Financial Studies*, 21(6), pp 2705–2742.

Acharya VV and T Yorulmazer (2008b), 'Information Contagion and Bank Herding', *Journal of Money, Credit and Banking*, 40(1), pp 215–231.

Afonso GM and HS Shin (2008), 'Systemic Risk and Liquidity in Payment Systems', Federal Reserve Bank of New York Staff Reports No 352, rev August 2010 (Precautionary Demand and Liquidity in Payment Systems).

Allen F, A Babus and E Carletti (2009), 'Financial Crises: Theory and Evidence', *Annual Review of Financial Economics*, 1, pp 97–116.

Allen F and E Carletti (2006), 'Credit Risk Transfer and Contagion', *Journal of Monetary Economics*, 53(1), pp 89–111.

Allen F and E Carletti (2013), 'Systemic Risk from Real Estate and Macro-Prudential Regulation', *International Journal of Banking, Accounting and Finance*, 5(1/2), pp 28–48.

Allen F, E Carletti and D Gale (2009), 'Interbank Market Liquidity and Central Bank Intervention', *Journal of Monetary Economics*, 56(5), pp 639–652.

Allen F, E Carletti and D Gale (forthcoming), 'Money, Financial Stability and Efficiency', *Journal of Economic Theory*.

Allen F, E Carletti, JP Krahnen and M Tyrell (2011), 'Introduction to Liquidity and Crises', in F Allen, E Carletti, JP Krahnen and M Tyrell (eds), *Liquidity and Crises*, Oxford University Press, New York, pp 3–32.

Allen F and D Gale (1998), 'Optimal Financial Crises', *The Journal of Finance*, 53(4), pp 1245–1284.

Allen F and D Gale (2000), 'Financial Contagion', *Journal of Political Economy*, 108(1), pp 1–33.

Allen F and D Gale (2003), 'Asset Price Bubbles and Stock Market Interlinkages', in WC Hunter, GG Kaufman and M Pomerleano (eds), *Asset Price Bubbles: The Implications for Monetary, Regulatory, and International Policies*, MIT Press, Cambridge, pp 323–336.

Allen F and D Gale (2004a), 'Financial Fragility, Liquidity, and Asset Prices', *Journal of the European Economic Association*, 2(6), pp 1015–1048.

Allen F and D Gale (2004b), 'Financial Intermediaries and Markets', *Econometrica*, 72(4), pp 1023–1061.

Allen F and D Gale (2007), *Understanding Financial Crises*, Clarendon Lectures in Finance, Oxford University Press, Oxford.

Antinolfi G, E Huybens and T Keister (2001), 'Monetary Stability and Liquidity Crises: The Role of the Lender of Last Resort', *Journal of Economic Theory*, 99(1–2), pp 187–219.

Bagehot W (1873), *Lombard Street: A Description of the Money Market*, H. S. King, London.

Berger AN and CHS Bouwman (2009), 'Bank Liquidity Creation', *The Review of Financial Studies*, 22(9), pp 3779–3837.

Berger AN and CHS Bouwman (2013), 'How Does Capital Affect Bank Performance During Financial Crises?', *Journal of Financial Economics*, 109(1), pp 146–176.

Bernanke BS (2010), 'Monetary Policy and the Housing Bubble', Speech to the Annual Meeting of the American Economic Association, Atlanta, 3 January.

Bhattacharya S and D Gale (1987), 'Preference Shocks, Liquidity, and Central Bank Policy', in WA Barnett and KJ Singleton (eds), *New Approaches to Monetary Economics: Proceedings of the Second International Symposium in Economic Theory and Econometrics*, International Symposia in Economic Theory and Econometrics, Cambridge University Press, Cambridge, pp 69–88.

Bolton P, T Santos and JA Scheinkman (2011), 'Outside and Inside Liquidity', *The Quarterly Journal of Economics*, 126(1), pp 259–321.

Brunnermeier MK and LH Pedersen (2009), 'Market Liquidity and Funding Liquidity', *The Review of Financial Studies*, 22(6), pp 2201–2238.

Brusco S and F Castiglionesi (2007), 'Liquidity Coinsurance, Moral Hazard, and Financial Contagion', *The Journal of Finance*, 62(5), pp 2275–2302.

Bryant J (1980), 'A Model of Reserves, Bank Runs, and Deposit Insurance', *The Journal of Banking and Finance*, 4(4), pp 335–344.

Calomiris CW and G Gorton (1991), 'The Origins of Banking Panics: Models, Facts, and Bank Regulation', in RG Hubbard (ed), *Financial Markets and Financial Crises*, University of Chicago Press, Chicago, pp 109–173.

Calomiris CW and CM Kahn (1991), 'The Role of Demandable Debt in Structuring Optimal Banking Arrangements', *The American Economic Review*, 81(3), pp 497–513.

Calomiris CW and JR Mason (2003), 'Fundamentals, Panics, and Bank Distress during the Depression', *The American Economic Review*, 93(5), pp 1615–1647.

Carlsson H and E van Damme (1993), 'Global Games and Equilibrium Selection', *Econometrica*, 61(5), pp 989–1018.

Case KE and RJ Shiller (1989), 'The Efficiency of the Market for Single-Family Homes', *The American Economic Review*, 79(1), pp 125–137.

Champ B, BD Smith and SD Williamson (1996), 'Currency Elasticity and Banking Panics: Theory and Evidence', *The Canadian Journal of Economics*, 29(4), pp 828–864.

Chari VV and R Jagannathan (1988), 'Banking Panics, Information, and Rational Expectations Equilibrium', *The Journal of Finance*, 43(3), pp 749–761.

Chen Q, I Goldstein and W Jiang (2007), 'Payoff Complementarities and Financial Fragility: Evidence from Mutual Fund Outflows', The Wharton School of the University of Pennsylvania, Rodney L White Center for Financial Research Working Paper 26–07.

Cifuentes R, G Ferrucci and HS Shin (2005), 'Liquidity Risk and Contagion', *Journal of the European Economic Association*, 3(2/3), pp 556–566.

Cooper R and D Corbae (2002), 'Financial Collapse: A Lesson from the Great Depression', *Journal of Economic Theory*, 107(2), pp 159–190.

Crowe C, G Dell'Ariccia, D Igan and P Rabanal (2011), 'How to Deal with Real Estate Booms: Lessons from Country Experiences', IMF Working Paper WP/11/91.

Dasgupta A (2004), 'Financial Contagion through Capital Connections: A Model of the Origin and Spread of Bank Panics', *Journal of the European Economic Association*, 2(6), pp 1049–1084.

Diamond DW (1997), 'Liquidity, Banks, and Markets', *Journal of Political Economy*, 105(5), pp 928–956.

Diamond DW and PH Dybvig (1983), 'Bank Runs, Deposit Insurance, and Liquidity', *Journal of Political Economy*, 91(3), pp 401–419.

Diamond DW and RG Rajan (2001), 'Liquidity Risk, Liquidity Creation, and Financial Fragility: A Theory of Banking', *Journal of Political Economy*, 109(2), pp 287–327.

Diamond DW and RG Rajan (2006), 'Money in a Theory of Banking', *The American Economic Review*, 96(1), pp 30–53.

Diamond DW and RG Rajan (2011), 'Fear of Fire Sales, Illiquidity Seeking, and Credit Freezes', *The Quarterly Journal of Economics*, 126(2), pp 557–591.

Eisenberg L and TH Noe (2001), 'Systemic Risk in Financial Systems', *Management Science*, 47(2), pp 236–249.

Elsinger H, A Lehar and M Summer (2006a), 'Risk Assessment for Banking Systems', *Management Science*, 52(9), pp 1301–1314.

Elsinger H, A Lehar and M Summer (2006b), 'Using Market Information for Banking System Risk Assessment', *International Journal of Central Banking*, 2(1), pp 137–165.

Englund P, JM Quigley and CL Redfearn (1998), 'Improved Price Indexes for Real Estate: Measuring the Course of Swedish Housing Prices', *Journal of Urban Economics*, 44(2), pp 171–196.

Fecht F (2004), 'On the Stability of Different Financial Systems', *Journal of the European Economic Association*, 2(6), pp 969–1014.

Fecht F, KG Nyborg and J Rocholl (2011), 'The Price of Liquidity: The Effects of Market Conditions and Bank Characteristics', *Journal of Financial Economics*, 102(2), pp 344–362.

Freixas X and C Holthausen (2004), 'Interbank Market Integration under Asymmetric Information', *The Review of Financial Studies*, 18(2), pp 459–490.

Freixas X and J Jorge (2008), 'The Role of Interbank Markets in Monetary Policy: A Model with Rationing', *Journal of Money, Credit and Banking*, 40(6), pp 1151–1176.

Freixas X, A Martin and D Skeie (2011), 'Bank Liquidity, Interbank Markets, and Monetary Policy', *The Review of Financial Studies*, 24(8), pp 2656–2692.

Freixas X, BM Parigi and J-C Rochet (2000), 'Systemic Risk, Interbank Relations, and Liquidity Provision by the Central Bank', *Journal of Money, Credit & Banking*, 32 (No 3 Part 2: What Should Central Banks Do?), pp 611–638.

Friedman M and AJ Schwartz (1963), *A Monetary History of the United States 1867–1960*, Studies in Business Cycles No 12, Princeton University Press, Princeton.

Furfine CH (2001), 'Banks as Monitors of Other Banks: Evidence from the Overnight Federal Funds Market', *The Journal of Business*, 74(1), pp 33–57.

Furfine CH (2002), 'The Interbank Market during a Crisis', *European Economic Review*, 46(4–5), pp 809–820.

Gai P and S Kapadia (2010), 'Contagion in Financial Networks', Bank of England Working Paper No 383.

Glaeser E and J Gyourko (2007), 'Housing Dynamics', Harvard Institute of Economic Research Discussion Paper No 2137.

Goldstein I and A Pauzner (2005), 'Demand–Deposit Contracts and the Probability of Bank Runs', *The Journal of Finance*, 60(3), pp 1293–1327.

Goodfriend M and RG King (1988), 'Financial Deregulation, Monetary Policy, and Central Banking', Federal Reserve Bank of Richmond *Economic Review*, 74(3), pp 3–22.

Gorton GB (1988), 'Banking Panics and Business Cycles', *Oxford Economic Papers*, 40(4), pp 751–781.

Gorton GB (2008), 'The Panic of 2007', in *Maintaining Stability in a Changing Financial System*, A Symposium sponsored by the Federal Reserve Bank of Kansas City, Kansas City, pp 131–262.

Gorton GB and L Huang (2004), 'Liquidity, Efficiency, and Bank Bailouts', *The American Economic Review*, 94(3), pp 455–483.

Heider F, M Hoerova and C Holthausen (2009), 'Liquidity Hoarding and Interbank Market Spreads: The Role of Counterparty Risk', ECB Working Paper No 1126.

Herring RJ and S Wachter (1999), 'Real Estate Booms and Banking Busts: An International Perspective', Wharton Financial Institutions Center Working Paper No 99–27.

Holmström B and J Tirole (1998), 'Private and Public Supply of Liquidity', *Journal of Political Economy*, 106(1), pp 1–40.

Holmström B and J Tirole (2011), *Inside and Outside Liquidity*, MIT Press, Cambridge.

Huang J and J Wang (2009), 'Liquidity and Market Crashes', *The Review of Financial Studies*, 22(7), pp 2607–2643.

Huang J and J Wang (2010), 'Market Liquidity, Asset Prices, and Welfare', *Journal of Financial Economics*, 95(1), pp 107–127.

Jacklin CJ and S Bhattacharya (1988), 'Distinguishing Panics and Information-Based Bank Runs: Welfare and Policy Implications', *Journal of Political Economy*, 96(3), pp 568–592.

Kahn C and J Santos (2008), 'Liquidity, Payment and Endogenous Financial Fragility', unpublished manuscript, Federal Reserve Bank of New York.

Kiyotaki N and J Moore (2005), '2002 Lawrence R. Klein Lecture: Liquidity and Asset Prices', *International Economic Review*, 46(2), pp 317–349.

Kiyotaki N and J Moore (2008), 'Liquidity, Business Cycles, and Monetary Policy', unpublished manuscript, Princeton University.

Leitner Y (2005), 'Financial Networks: Contagion, Commitment, and Private Sector Bailouts', *The Journal of Finance*, 60(6), pp 2925–2953.

Lorenzoni G (2008), 'Inefficient Credit Booms', *The Review of Economic Studies*, 75(3), pp 809–833.

Morris S and HS Shin (1998), 'Unique Equilibrium in a Model of Self-Fulfilling Currency Attacks', *The American Economic Review*, 88(3), pp 587–597.

Morris S and HS Shin (2009), 'Illiquidity Component of Credit Risk', unpublished manuscript, Princeton University.

Rauch C, S Steffen, A Hackethal and M Tyrell (2010), 'Determinants of Bank Liquidity Creation', unpublished manuscript, Goethe University Frankfurt.

Reinhart CM and KS Rogoff (2009), *This Time is Different: Eight Centuries of Financial Folly*, Princeton University Press, Princeton.

Repullo R (2005), 'Liquidity, Risk Taking, and the Lender of Last Resort', *International Journal of Central Banking*, 1(2), pp 47–80.

Rochet J-C and X Vives (2004), 'Coordination Failures and the Lender of Last Resort: Was Bagehot Right After All?', *Journal of the European Economic Association*, 2(6), pp 1116–1147.

Skeie D (2008), 'Banking with Nominal Deposits and Inside Money', *Journal of Financial Intermediation*, 17(4), pp 562–584.

Smith BD (2002), 'Monetary Policy, Banking Crises, and the Friedman Rule', *The American Economic Review*, 92(2), pp 128–134.

Taylor JB (2008), 'The Financial Crisis and the Policy Responses: An Empirical Analysis of What Went Wrong', unpublished manuscript, Stanford University.

Upper C (2011), 'Simulation Methods to Assess the Danger of Contagion in Interbank Markets', *Journal of Financial Stability*, 7(3), pp 111–125.

Upper C and A Worms (2004), 'Estimating Bilateral Exposures in the German Interbank Market: Is There a Danger of Contagion?', *European Economic Review*, 48(4), pp 827–849.

Wicker E (1980), 'A Reconsideration of the Causes of the Banking Panic of 1930', *Journal of Economic History*, 40(3), pp 571–583.

Wicker E (1996), *The Banking Panics of the Great Depression*, Studies in Monetary and Financial History, Cambridge University Press, Cambridge.

General Discussion

The paper by Franklin Allen and Elena Carletti was well received and prompted discussion across a broad range of topics. One discussion centred on the potential for asset market mispricing, with deviations from fundamentals due to panics or overconfidence, and the systemic effects that this can have. Professor Allen stated that asset prices typically looked fine until one had the benefit of hindsight after a crisis had occurred. In his view, bubbles were harmful to the economy, rejecting the MIT view that efficient bubbles can exist and, indeed, may be beneficial in some circumstances.

In response to a question about whether the academic literature had much to say about why core-periphery structures were common in financial markets, Professor Allen commented that the endogenous formation of core-periphery structures was not well understood. He suggested that there must be a more important fundamental cause for this type of structure to evolve than merely regulatory arbitrage. Another participant noted that if core-periphery structures evolved endogenously to remove the need for expensive collateral, as had been suggested in the literature, then some post-crisis regulatory change could be offsetting these forces. Information asymmetries were cited as another potential driving factor in these developments.

The importance of information was also raised. One participant asked about what had been learned from the global games literature, where the equilibrium reached depends on the nature of public and private information. In particular, they asked about the policy implications arising from fire-sale externalities, whereby illiquid firms are forced to sell assets at detrimentally low values in order to stay liquid, resulting in bad equilibria.

Another discussion considered whether policymakers had a sufficiently systemic perspective in dealing with crises. It was noted that without this perspective there was a tendency for policymakers to 'fight the last war'. The ability of policymakers to effectively minimise systemic risk by tempering risky activity was also discussed. One participant asked whether empirical evidence suggested that macroprudential policy tools such as LVRs were effective. Evidence from Italy was cited to suggest that while LVR restrictions could dampen house prices in the short run, this effect was not sustained in the long run.

Another participant raised the issue of bank runs, pondering why they were conspicuously rare during the recent financial crisis. Implicit government guarantees on deposits, potential naivety of depositors, and less reliance on deposits due to asset diversification were all noted as potential contributors to this stability. Professor Allen posited that standard models of rationality were not particularly successful in resolving this issue.

The precise role banks play in the global economy was also discussed. One participant suggested that large corporations had the scale and credibility to participate in funding markets directly, with the corollary that banks should focus on servicing the funding needs of small and medium enterprises (SMEs). In response, Professor Allen noted that the reason for layers of financial intermediation were also not well understood, but agreed that the need for banks to facilitate funding of firms had not disappeared.

Another discussion concerned liquidity regulation. One participant noted that the provision of liquidity by central banks during crises was well understood as a public good, and that the resulting moral hazard issue could be offset by regulation, such as liquidity requirements. However, they also suggested that it was not well understood whether it was necessary to address these concerns through regulation, or whether these systemic concerns could be left to the central bank to deal with. With respect to liquidity requirements, participants generally agreed that it was more efficient for the financial sector to hold liquid assets, rather than for corporations (the end users of financial services) to hold these assets directly. Professor Allen further argued that it was particularly inefficient for the private sector to hold large amounts of liquid assets because these holdings were still likely to be insufficient when large negative systemic shocks eventuated.

Central Bank Liquidity Provision and Core Funding Markets

Grahame Johnson and Eric Santor*

1. Introduction

The global financial crisis can be divided into three distinct phases – Phase I: a contained banking crisis (July 2007 to August 2008); Phase II: financial system collapse and global recession (September 2008 to April 2009); and Phase III: euro area sovereign debt and banking crisis (April 2010 to December 2012). In this paper, we examine how the evolution of the financial crisis can be explained from the perspective of a system-wide liquidity shock that hit funding markets in both the conventional banking and market-based financing (or shadow banking) sectors. While a significant shock to any of the broader funding markets would be likely to have negative economic implications, there is a subset of markets (the *core funding markets*) that lie at the centre of the financial system for which shocks of sufficient magnitude could have potentially catastrophic consequences. Given their centrality to the financial system, it was the runs in these core funding markets that defined the crisis. Subsequently, it was the policy interventions by central banks in these markets, complemented by the actions of the fiscal authorities, that allowed the recovery to take hold.

From this experience, it is clear that central banks need to continue to ensure that core funding markets remain functional at all times. This means that central banks need to be prepared, if necessary, to assume a key role in core funding markets in times of severe financial stress. In effect, the central bank's lender of last resort function must be extended to core funding markets. This commitment, however, must be balanced by measures to address moral hazard, protect taxpayer resources, and ensure the efficient functioning of markets in normal circumstances. To this end, we offer a vision for this role in the evolving global financial system.

The paper proceeds as follows. We first describe the three phenomena that contributed to the crisis: leverage, financial globalisation, and inadequate financial regulation and supervision. In Section 3, we examine the shadow banking system and market-based funding. This is followed by the definition of core funding markets in Section 4. Their centrality to the financial crisis is then explored in Section 5. Section 6 examines the role of central banks in core funding markets during the crisis, and Section 7 gives some examples of these actions. Section 8 concludes with a discussion of the future role of central banks in core funding markets.

* The views expressed here are those of the authors and are not necessarily those of the Bank of Canada.

2. The Global Financial Crisis: Preconditions for a Run on Financial Markets

An extensive literature has examined the underlying causes of the global financial crisis, with respective studies identifying a range of potential factors (Obstfeld and Rogoff 2010). Broadly speaking, in our view, the global financial crisis was fed by three self-reinforcing phenomena: a 30-year secular increase in leverage, financial globalisation, and, driven by a search for yield, excessive risk-taking in a context of inadequate regulation and supervision (Carney 2011).

2.1 Leverage

The first phenomenon was the seemingly unprecedented accumulation of debt over the past 30 years in the advanced economies (Figure 1).[1] Household debt rose dramatically, doubling over the period and surpassing 100 per cent of GDP in some cases, while corporate debt rose by close to 50 per cent. Likewise, government debt more than doubled as a share of GDP over the period (Cecchetti, Mohanty and Zampolli 2011). While government leverage was in some cases falling in the run-up to the crisis, this improvement in public finances was misleading – in fact, many countries were building significant structural deficits that were obscured by artificially strong pre-crisis growth.

Figure 1: Household, Non-financial Corporate and Government Debt
Per cent of GDP

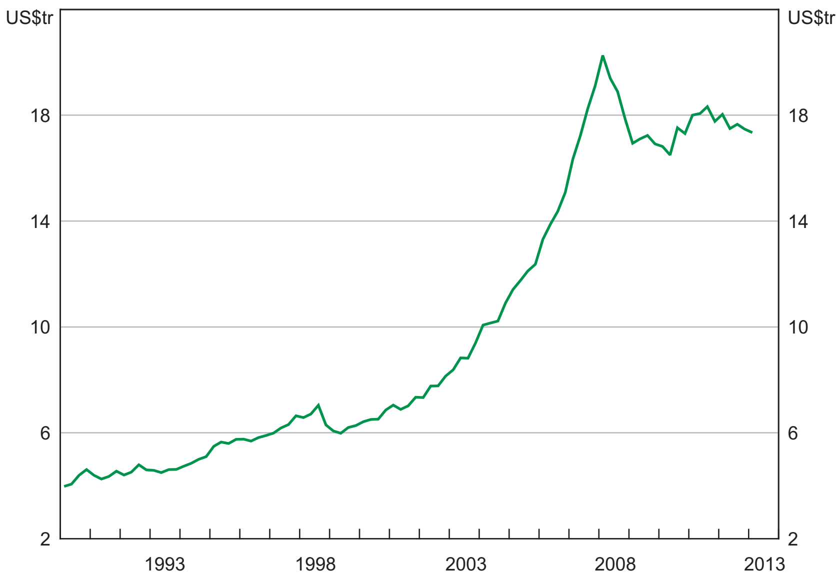
Note: Some of the 2010 data refer to 2009
Source: Cecchetti, Mohanty and Zampolli (2011)

1 There are many reasons why debt has increased relative to incomes over the past three decades, including financial development (deepening and broadening), and lower economic volatility and interest rates due to the Great Moderation.

2.2 Cross-border lending

The second phenomenon was the ongoing globalisation of finance. Since the 1970s, capital flows have increased at roughly twice the rate of growth of trade (which has typically increased at twice the rate of growth of GDP), with a particular acceleration in the lead up to the crisis. Importantly, this increase in capital flows often took the form of cross-border lending by banks, much of it in foreign currency (McGuire and von Peter 2009). Between 2000 and 2007, claims on non-residents rose from roughly US$6.5 trillion to more than US$19 trillion (Figure 2).

Figure 2: World Banking Claims on Non-residents in Foreign Currency

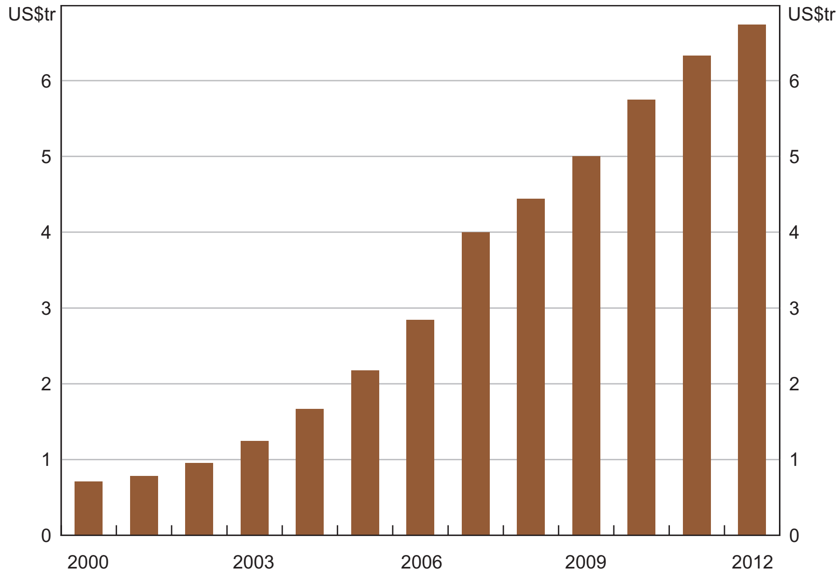


Note: Individual foreign currencies are converted to US dollars using average exchange rates for the quarter
Source: Bank for International Settlements

In particular, cross-border lending expanded rapidly in the euro area, as the apparent end to exchange rate risk led to substantial capital flows and a compression of spreads. This led to large imbalances, and some peripheral countries accumulated deficits in their net international investment positions of close to 100 per cent of GDP.

This increase in private capital flows was matched by a complementary increase in 'public capital flows' in the form of reserve accumulation, as many emerging market economies (EMEs) pursued export-led growth strategies (Figure 3). This uphill flow of capital from EMEs to the advanced economies helped to suppress long-term interest rates in the United States (and perhaps elsewhere), resulting in a subsequent search for yield by investors in the advanced economies (Bernanke 2005).

Figure 3: Growing Levels of Emerging Market Reserves



Note: Data are the sum of foreign exchange reserves from the following countries: Argentina, Brazil, Bulgaria, Chile, China, Columbia, the Czech Republic, Ecuador, Egypt, Hungary, India, Indonesia, Lebanon, Malaysia, Mexico, Morocco, Nigeria, Peru, Philippines, Poland, Romania, Russia, Saudi Arabia, South Africa, South Korea, Thailand, Turkey, Ukraine, United Arab Emirates and Venezuela

Source: IMF, International Financial Statistics

2.3 Financial regulation and supervision

The increase in leverage and cross-border exposures was made possible by a third phenomenon – rapid financial innovation and risk-taking in an environment of inadequate regulation and lax supervision. The search for yield in an environment of 'low for long' interest rates contributed to the demand for, and creation of, a range of complex structured products. These products included a set of 'AAA-rated' financial instruments based on pools of subprime mortgages, called collateralised debt obligations (CDOs). These CDOs typically contained different 'tranches', which reflected the underlying credit risk contained in the pool of assets. CDOs had three main features that would contribute to the severity of the crisis (Brunnermeier 2009).[2]

1. **Originate to distribute.** Historically, banks offering loans would typically hold these assets on their balance sheet. However, by securitising a pool of loans and selling it as a CDO, a bank could off-load the risk onto other investors (this would also reduce the need to hold capital against these assets). These investors were, in principle, better placed to handle this risk. The main problem with this model is that it lowered the incentives for the bank to screen the quality of the borrowers, as it would not bear the risk. This behaviour contributed to a dramatic decline in lending standards. At the same time, the complexity and opacity of CDO

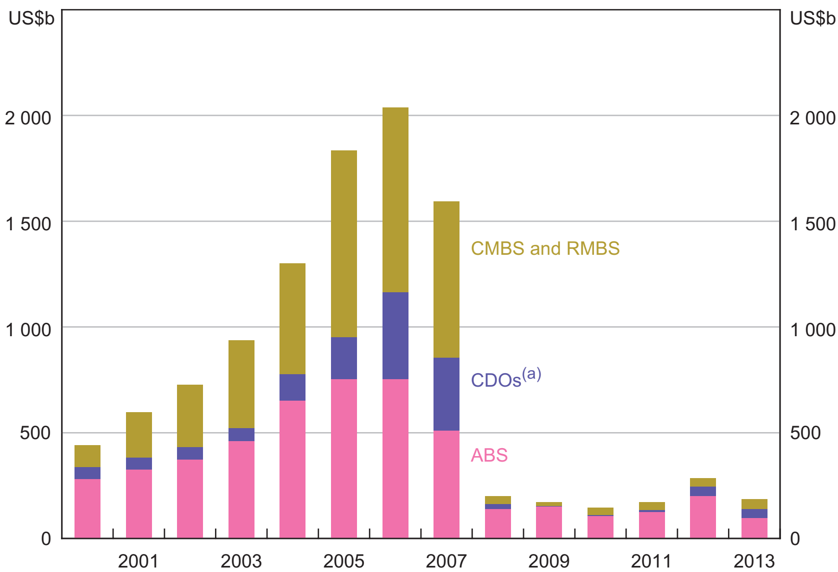
2 Another contributing factor was that prior to the crisis, housing prices had not fallen on a national basis in the United States since data had been collected. Consequently, earlier vintages of subprime loans, when defaults did occur, did not result in losses for banks, as rising house prices meant that the collateral value of the house would offset any potential losses. Markets failed to account for this effect when assessing the losses given default on subprime mortgages.

structures meant that investors were often purchasing assets about which they understood very little. Driven by a search for yield, investors were assuming higher risk (even if this was not entirely clear at the time). In many cases, demand for these assets came from foreign investors, who in fact had the perception that these assets were 'safe' (Bernanke 2011).

2. **Maturity transformation.** CDOs and other types of securitisation often utilised a funding model that relied on maturity transformation. In this case, special purpose vehicles were set up such that longer-term assets (such as a pool of subprime mortgages in the form of a CDO) were funded by shorter-term paper. Credit lines were established by the sponsoring bank as 'liquidity backstops' in case there were difficulties in rolling over the short-term paper (Brunnermeier 2009). The result was a funding model that relied excessively on short-term funding.

3. **Capital and the repo market.** Since many CDOs were held 'off-balance' sheet, they required little or no capital. Those CDOs that were in the pipeline to be sold were also, often inappropriately, generally given very high credit ratings (Jaffee *et al* 2009). These high credit ratings allowed the underlying assets to be used in the repo market as a source of funding. The net effect was that banks were able to increase their leverage, and held far too little capital given the underlying risks to the balance sheet. These three features of CDOs were a key factor behind their rapid expansion – between 2000 and 2007, CDO issuance in the United States rose rapidly (Figure 4), constituting a growing part of the overall market for asset-backed securities (ABS).

Figure 4: United States – Non-agency Securitisation Issuance



Notes: Year to July 2013; CMBS denotes commercial mortgage-backed securities, RMBS denotes residential mortgage-backed securities, ABS denotes asset-backed securities
(a) Collateralised debt obligations (CDO) issued in US dollars

Source: Securities Industry and Financial Markets Association

When combined with the larger trends of leveraging, globalisation and lax supervision and regulation, the issuance of CDOs contributed to both the severity and persistence of the crisis. When the first indications that subprime mortgage-backed securities were going to incur losses, the impact was amplified considerably for several reasons:

- The opacity of the CDO structure meant that it was effectively impossible for investors to determine which CDOs held 'bad' assets and which were generally sound. This information asymmetry problem contributed to the collapse of the entire CDO market.
- Ongoing integration of global financial markets meant it was particularly unclear which financial institutions held similar types of debt – and thus fears about counterparty risk were global, not just domestic.
- Counterparty risk was compounded by inadequate regulation and supervision – bank leverage was extremely high and capital buffers were insufficient given the scale of losses.
- As doubt was cast on the value of subprime-related assets, the problem was quickly amplified and cascaded. Falling collateral values led to the impairment of the repo market.
- As the repo market became impaired, collateralised funding for a range of markets dried up forcing fire sales, further depressing asset prices.
- In many cases, funding was in foreign currency (European banks funding CDOs with short-term US dollar paper) which compounded the impairment in funding markets.

As risk was rapidly and brutally repriced through the global financial system, financial markets faced 'runs' of an unprecedented nature, spanning both the conventional banking sector and the shadow banking sector. In particular, it was the runs in the core funding markets that led to the failure of many financial institutions in the second half of 2008. Likewise, it was the subsequent intervention by central banks and fiscal authorities in these markets that forestalled a complete collapse of the financial system. The crisis did not end in 2009, however, as the imbalances that had built up in the euro area still needed to be unwound. Again, the stresses caused by the resolution of these imbalances would emerge in core funding markets. In what follows, we examine more closely the shadow banking sector and its relationship to core funding markets.

3. Shadow Banking and the Role of Market-based Funding

The shadow banking sector facilitated many of the developments highlighted above that led to the financial crisis, especially the increase in system-wide leverage and the prevalence of subprime-related CDOs. The Financial Stability Board (FSB) describes shadow banking as 'credit intermediation involving entities and activities outside the regular banking system' (FSB 2012). In defining the shadow banking system, the FSB follows a two-step approach:

- look at all non-bank credit intermediation
- focus on the subset of non-bank credit intermediation where there are: (i) developments that increase systematic risk (maturity/liquidity transformation, imperfect credit risk transfer, and/or leverage); and/or (ii) indications of regulatory arbitrage.

In following this approach, the FSB uses an entity-based definition for its monitoring exercises. Specifically, the size of the shadow banking sector is based on assets held by 'other financial institutions' (OFIs), which are entities that lie outside of the traditional banking sector. This includes hedge funds, money market mutual funds, finance companies and structured investment vehicles. The key findings of the 2012 monitoring report are as follows:

- Globally, the shadow banking sector rose rapidly from US$26 trillion in 2002 to US$62 trillion in 2007. As the crisis hit, the size of the total market declined slightly in 2008 – however, it would soon expand again, and increased to US$67 trillion by 2011. The shadow banking system's share of total financial intermediation has decreased since the crisis, although it remains at around 25 per cent (after having peaked at 27 per cent in 2007).
- There is considerable divergence across jurisdictions in terms of the relative size of the shadow banking system, the range of activities undertaken and the growth trends. The shadow banking sector in the United States has one of the larger shares (35 per cent of total financial assets are held by OFIs), while the euro area (30 per cent) and the United Kingdom (25 per cent) are also relatively large. Germany's shadow banking sector is relatively small (15 per cent).

Under the entity-based definition, Canada's shadow banking system is relatively small (under 10 per cent of total financial assets). The entity-based measure, however, excludes shadow banking activities undertaken by banks that may, nonetheless, contribute to systemic risk. This is particularly relevant for a country like Canada, in which the large banks are the most significant participants in domestic capital markets.

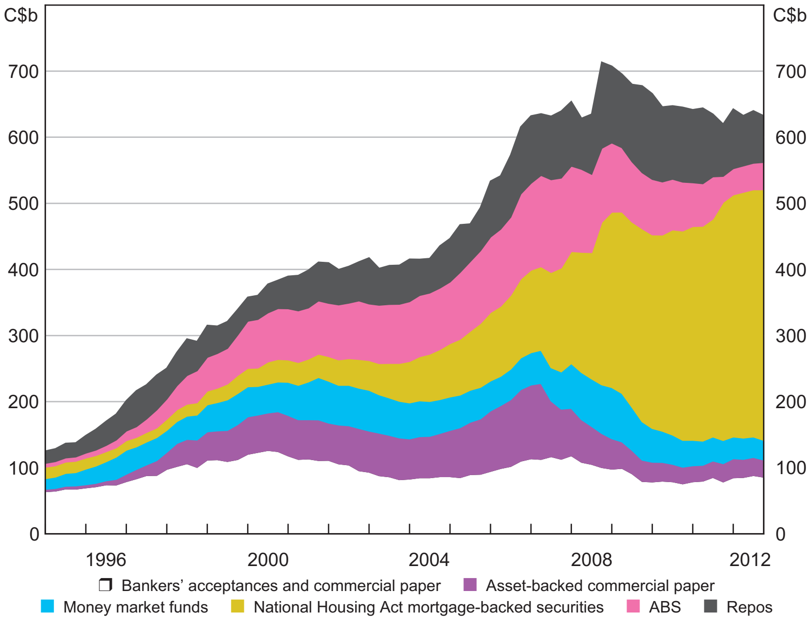
An alternative is to use an activity-based approach, focusing on bank-like intermediation activities that are conducted primarily through financial markets. This approach captures such activities as repos and securitisations and thus provides a more accurate description of the relative importance of market-based funding activities for a given jurisdiction, particularly given the predominance of the banks in a number of these markets in Canada (Figure 5; Gravelle, Grieder and Lavoie 2013).

Under this definition, the size of shadow banking activity in Canada grew significantly in the period leading up to the financial crisis, reaching a level close to 60 per cent of the traditional banking sector (Figure 6). It has, however, subsequently declined and currently stands at roughly 40 per cent of the traditional banking sector's size. The size of the Canadian shadow banking sector is estimated to be roughly 40 per cent of GDP (compared with approximately 95 per cent for the United States).

While this approach focuses on activities rather than entities, it is consistent with the FSB approach in that it focuses on the extent to which shadow banking activities exhibit any or all of the following four risk factors:

- maturity transformation – long-term assets financed with short-term liabilities
- liquidity transformation – the underlying assets being financed are relatively illiquid
- leverage
- imperfect credit risk transfer – some credit exposure is held off-balance sheet or implicit support is provided by an entity.

Figure 5: Canada – Components of the Shadow Banking Sector



Sources: Bank of Canada; Canada Housing and Mortgage Corporation; DBRS; The Investment Funds Institute of Canada

Figure 6: Canada – Estimated Size of the Shadow Banking Sector

Per cent of traditional bank liabilities

Sources: Bank of Canada; Canada Housing and Mortgage Corporation; DBRS; The Investment Funds Institute of Canada

The Canadian shadow banking sector is made up of five main subsectors:

1. Government-backed mortgage securitisations (60 per cent).
2. Private-label securitisations (10 per cent).
3. Repurchase agreements (repos) (10 per cent).
4. Money market mutual funds (5 per cent).
5. Short-term unsecured debt (bankers' acceptances (BAs) and commercial paper (CP)) (15 per cent).

Each of these markets contains at least one of the four risk factors cited above, and could therefore be vulnerable to runs. In such markets, runs are generally triggered by information asymmetry. Specifically, a number of the underlying (securitised) products that support the shadow banking system lack full transparency. Opacity around the underlying assets that support securitisations can lead to valuation uncertainty. This greatly reduces the liquidity of the products, often making it impossible to roll over short-term financing for longer-term assets (impairing both the maturity and liquidity transformation functions). Furthermore, uncertainty about the distribution of underlying losses raises concerns about counterparty risks, which can lead to disruption in other shadow banking markets (such as repos and short-term unsecured debts). Under these circumstances, the shadow banking funding markets can freeze up and participants can become increasingly unwilling to deal with each other. Given the importance of these markets, such disruptions can lead to systemically important shocks, spreading to a range of other markets and institutions, ultimately affecting a far wider range of financial activities than the five sectors outlined above. This suggests a role for central banks in ensuring that the critical (that is, core) funding markets can operate continuously, even in times of extreme stress.

4. Identifying Core Funding Markets

There is a high level of interconnectedness between the shadow banking sector and the broader set of traditional financial markets and institutions (FSB 2012). In particular, the shadow banking system plays a large role in providing funding liquidity to both financial institutions and market makers. As such, a number of shadow banking activities could be considered systemically important in that shocks to these markets can spread to other financial markets and institutions. Moreover, there is a subset of markets that lies at the centre of the financial system for which such a shock would have catastrophic consequences. These *core funding markets* are necessary to the process of generating liquidity within the financial system itself. If one of them disappeared, there would be no substitute for its function. They therefore need to function continuously (Carney 2008a; Fontaine, Selody and Wilkins 2009).

Financial institutions and other market participants use core funding markets for two main purposes. First, these markets allow the funding of temporary mismatches between financial inflows and outflows, providing necessary operating liquidity for financial institutions to function. Second, core funding markets allow market makers to finance long positions and cover short positions. This supports transactions across the full range of financial markets and supports broad market liquidity. A failure of core funding markets, generated either through liquidity hoarding by counterparties or a reduction in market-making activity, could result in a 'liquidity spiral' (Brunnermeier and Pedersen 2009), creating a generalised liquidity crisis.

More formally, the Bank of Canada has defined a core funding market as having the following three characteristics (Fontaine *et al* 2009):

1. It is an important source of funding for the institutions, market makers and governments at the centre of the financial system.
2. There is no immediate substitute for this funding source.
3. If the market ceases to function, there is likely to be important contagion between major institutions and markets.

Given that the specific structure of financial systems varies across time and jurisdictions, the specific core funding markets will vary accordingly. Nonetheless, it is unlikely that there would be much variation in core funding markets across the major advanced economies.

Given this definition, the Bank of Canada has identified the following five markets as core.

1. **Sovereign debt (Government of Canada bonds and treasury bills).** The sovereign debt market is at the core of the financial system in most countries. This market provides the necessary funds that the federal/central government, which is the ultimate guarantor of the stability of the financial system, needs to operate. As well, in most jurisdictions, sovereign debt plays a critical role in financial markets, being used as a pricing reference, a hedging vehicle, a liquidity management tool in the banking system and a risk-free asset. There is no substitute for this market, and any material disruption would have severe consequences for the financial system.
2. **Repo markets.** These markets provide collateralised funding and are used extensively by market participants (both banks and shadow banking entities) to finance their inventories of securities. Repo markets are central to the 'securitised banking' system (Gorton and Metrick 2009), and dislocations (or runs) in this market result in a massive withdrawal of liquidity from the financial system.[3]
3. **Securities lending.** While relatively small in size, securities lending markets facilitate a range of financing activities for both the cash and repo markets. As well, securities lending facilitates the efficient use of collateral within the financial system.
4. **Unsecured private money markets.** Not all private sector unsecured markets are (or should be) core and, in Canada, this designation would only apply to the market for BAs. BAs are used by both banks and their clients for short-term liquidity management. Importantly, BAs can also substitute for both CP and asset-backed commercial paper (ABCP).
5. **Foreign exchange.** Both spot and foreign exchange swap markets are core markets, as without them neither domestic financial institutions with foreign liabilities nor international institutions with Canadian dollar liabilities would be able to manage their funding activities. This would force these institutions into their domestic markets, potentially forcing them to fund foreign assets with domestic borrowings. There is no substitute for the ability to transact in foreign exchange (FX) markets. The FX market does represent a particular challenge, however, as domestic authorities are constrained in the amount of FX liquidity they can provide to their financial system.

3 There is a significant amount of literature (e.g. Gorton 2009) that cites a run on certain parts of the repo market in the United States as the link that led from losses in the market for US subprime mortgages to a global financial and economic crisis.

For these core markets to function properly, they need adequate liquidity. Under normal circumstances, these markets endogenously generate sufficient liquidity such that they can operate efficiently and effectively with no external support. These markets are, however, vulnerable to shocks. Large shocks, either endogenous or exogenous, can lead to 'runs' in these core markets. Under these circumstances, keeping core funding markets continuously open requires appropriate policies and interventions, including central bank support.

5. Runs in Core Funding Markets

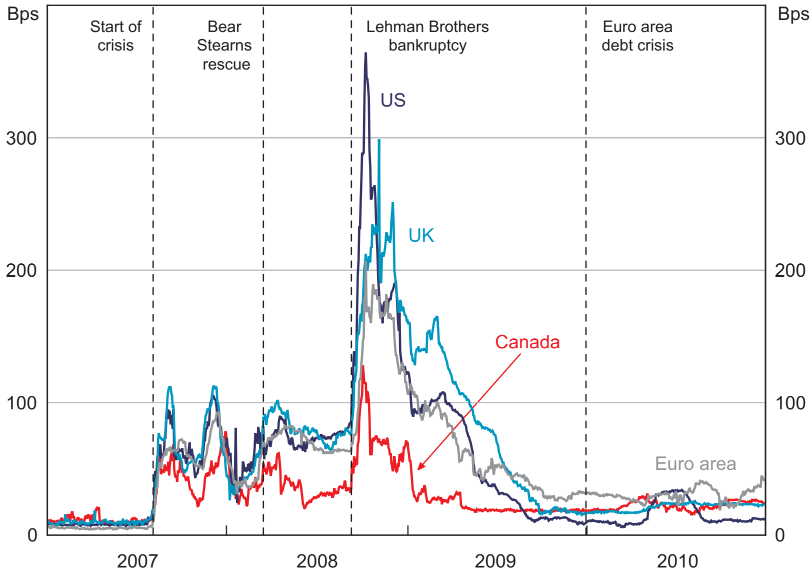
The increases in leverage, cross-border lending and rapid financial sector innovation were intimately tied to developments in the provision of market-based funding. The vulnerabilities arose not only from the size and scope of the shadow banking activities themselves, but also from the high degree of interconnectedness between the shadow banking system and both the broader financial markets and the traditional banking system. Banks and shadow banking (both entities and activities) are highly interconnected, with banks often playing a large role (either directly or indirectly) in the shadow banking credit intermediation chain. One of the key lessons emerging from the crisis is that shocks originating in the shadow banking sector can quickly propagate to core funding markets and institutions.

Due to this degree of interconnectedness, the sharp declines in the value of US subprime mortgages and the associated securitisations were quickly transformed into a system-wide shock, spreading to a broad range of market-based funding markets, both structured and traditional. Ultimately, the crisis led to the loss of market access for a number of European sovereigns. Indeed, the financial crisis has been referred to as a 'system-wide bank run', with the only difference between this event and prior bank runs being that it largely took place outside of the traditional banking sector (Gorton and Metrick 2009). The results were, however, very similar. Funding liquidity vanished as markets froze and counterparties became increasingly reluctant to transact with each other, almost irrespective of the quality of collateral being used to support the activities. This was equivalent to a massive withdrawal of liquidity from the financial system due to the impairment of core funding markets. In what follows, we highlight how core funding markets behaved during the respective phases of the crisis.

5.1 Phase I: July 2007 to August 2008

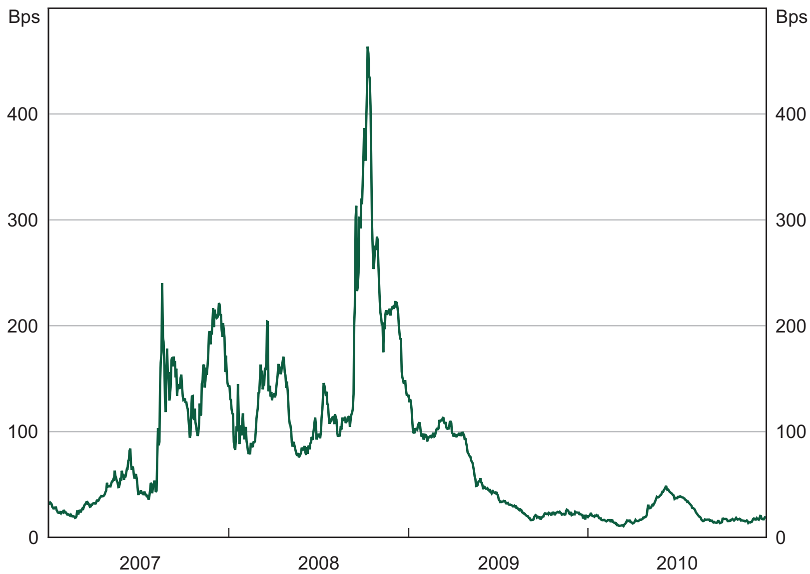
The first signs of the coming crisis emerged in mid 2007, as several funds exposed to subprime mortgage-based CDOs were suspended or frozen (Brunnermeier 2009), leading to losses at several banks. As these losses were reported, concerns about counterparty risk emerged, leading to a direct impact on prices in core funding markets. LIBOR-OIS spreads in a number of jurisdictions rose to roughly 100 basis points (Figure 7) from the previously suppressed levels of less than 10 basis points. Since many of the affected banks were based in Europe, tensions began to appear in the foreign exchange market as seen in the TED spread (Figure 8) and FX swap rates (Figure 9). Concerns about counterparty risks also appeared in other funding markets. For example, CP rates increased (Figure 10) and, as tension in the repo market affected the ability to fund other forms of ABS, auto and consumer debt ABS prices fell (Figure 11).

Figure 7: 3-month LIBOR-OIS Spread
Daily



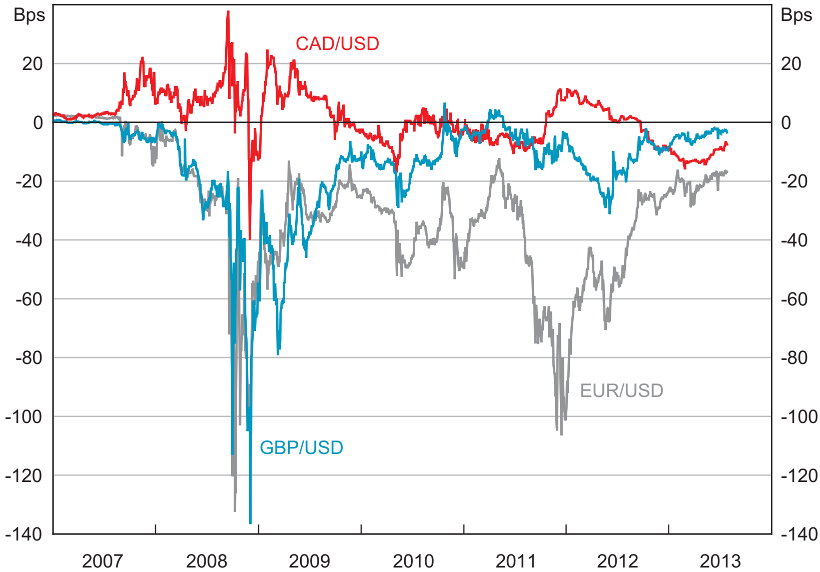
Notes: The LIBOR-OIS spread is the difference between the London Interbank Offered Rate (or equivalent) and the Overnight Index Swap; it is a measure of stress in the money markets
Sources: Bank of Canada; Bloomberg

Figure 8: TED Spread during the Financial Crisis
Daily



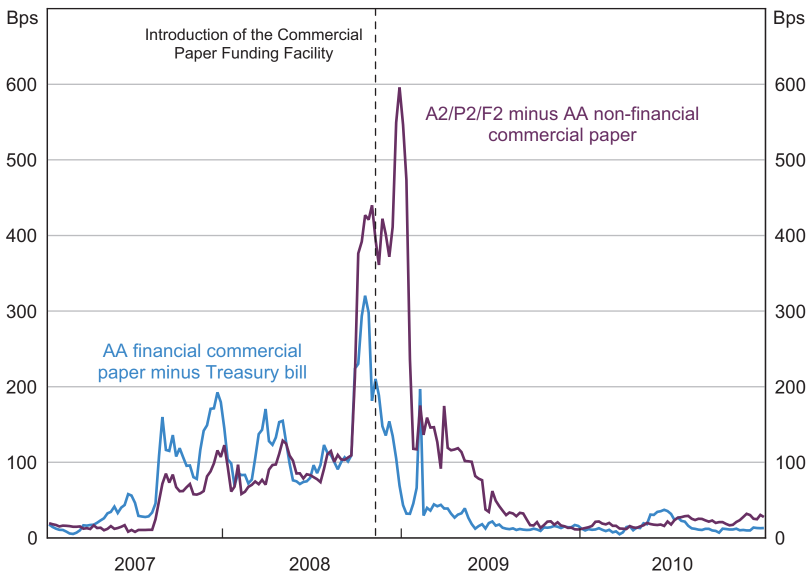
Notes: The TED spread is the difference between the 3-month T-bill rate, which measures the short-term rate on US government debt, and the 3-month LIBOR, which measures the interest rate on interbank loans; it is used as an indicator of perceived credit risk in the global economy
Source: Bloomberg

Figure 9: 1-year FX Swap Rates
Daily



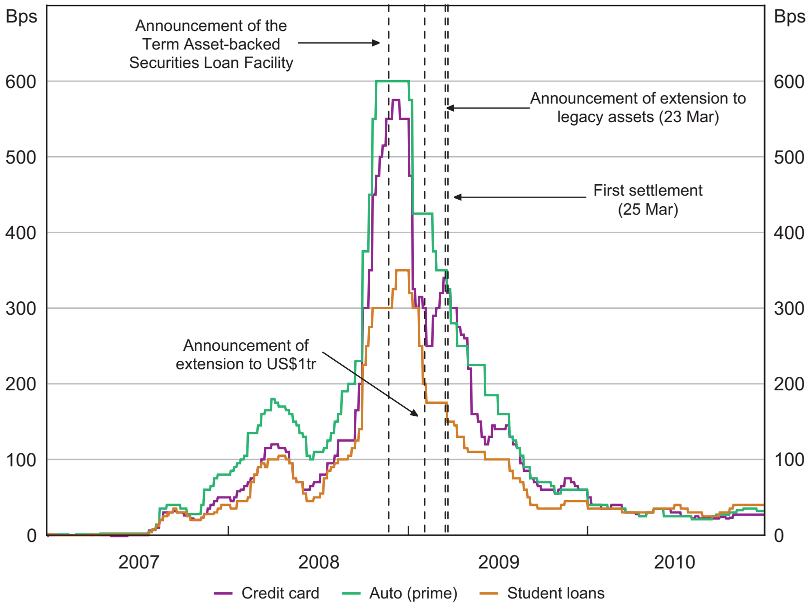
Source: Bloomberg

Figure 10: Spreads in the US Commercial Paper Market
Weekly



Source: Board of Governors of the Federal Reserve System

Figure 11: Spread of AAA 3-year Asset-backed Securities against 1-month LIBOR
By asset type, daily



Source: JPMorgan

While the respective core funding markets suffered shocks, the run remained relatively contained through the first half of 2008. Although markets were stressed and banks were reporting large subprime-related losses, funding markets remained sufficiently liquid due to two main factors. First, the major central banks introduced measures to ease tensions in the key interbank markets (e.g. the Federal Reserve's Term Auction Facility (TAF) program; and the European Central Bank's (ECB's) open market operations (OMOs)). Second, the Fed supported the purchase of Bear Stearns by JPMorgan, which seemingly reassured markets that no large systemically important bank would be allowed to fail.

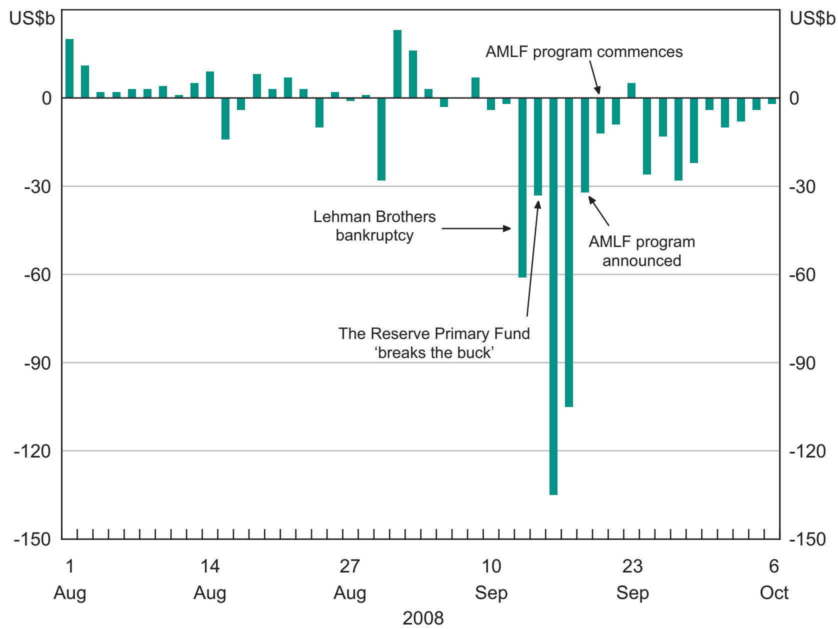
While the crisis appeared to remain contained through the first half of 2008, this state of affairs did not last for long. Despite ongoing growth in the global economy, the United States entered a recession and housing market activity and prices continued to decline. The underlying imbalances in the financial system had not been rectified, and further losses could be expected. These tensions came again in full force as Lehman Brothers lurched towards insolvency in early September 2008. However, it would not be bailed out.

5.2 Phase II: September 2008 to April 2009

The subsequent failure of Lehman Brothers in mid September 2008 led to a massive run in most core funding markets, but on a scale far beyond that experienced earlier in the year. Interest rates in a number of funding markets, both core and ancillary, rose sharply, as seen in LIBOR-OIS spreads, CP interest and FX swap rates, and rates on other forms of ABS (Figures 7 to 11). Likewise, quantities became severely impaired, as many banks were shut out of these markets and resorted to central bank facilities when possible. At the same time, pressures in the US dollar market became acute for many European banks, as evidenced by very sharp moves in both EUR/USD basis swaps and the TED spread.

These stresses and dislocations spread to other markets. Stress in US repo markets deepened, as evidenced by the increase in spreads between agency (and agency mortgage-backed securities) repo rates relative to general collateral (Copeland, Martin and Walker 2011). Likewise, money market mutual funds (MMMFs) started to experience massive outflows after one fund 'broke the buck' (Figure 12). These flows were only staunched in response to interventions by the US Federal Reserve and US Treasury.

Figure 12: Prime Money Market Mutual Fund Asset Changes



Note: AMLF denotes Asset-backed Commercial Paper Money Market Mutual Fund Liquidity Facility
Source: iMoneyNet

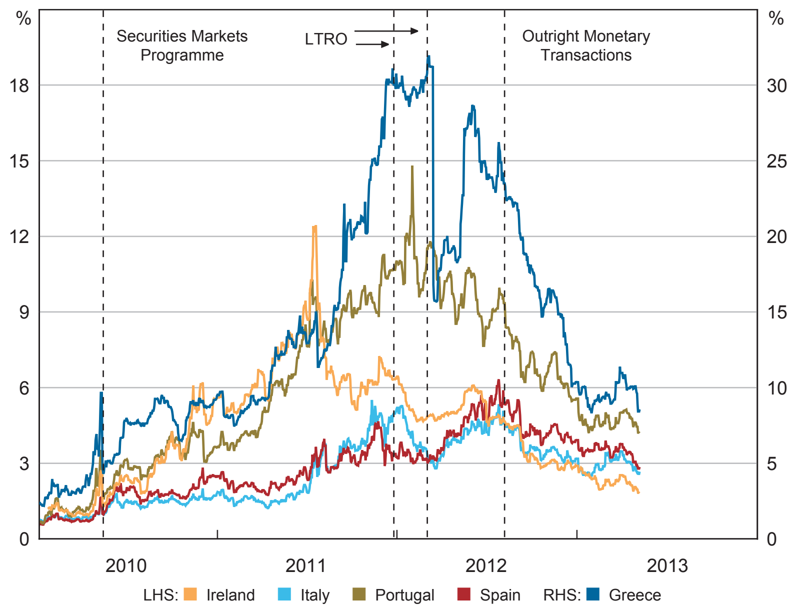
As the financial crisis deepened towards the end of 2008, the real economy also faltered, and sharp declines in activity were registered across most advanced economies as credit dried up and confidence was severely shaken. The inability of the financial system to provide funding for real activity was due to the failure of core funding markets. Subsequently, it was only the concerted actions of policymakers that prevented the Great Recession from becoming something even worse (see Section 6).

5.3 Phase III: April 2010 to December 2012

While European interbank markets were also severely affected, the inherent flexibility of the ECB's OMOs (and related collateral policy) appeared to be successful in mitigating some of the worst aspects of the crisis for European core funding markets. Moreover, since shadow banking was less prevalent in the euro area, the damage to what constituted the 'core funding markets' was less severe. However, the impact of the risks was merely delayed.

In early 2010, revelations that Greece's fiscal position was much worse than reported led to a sharp increase in its bond yields, and contagion to other peripheral bond market spreads as their fiscal positions came into question (Figure 13).

Figure 13: Euro Area Periphery – 10-year Generic Bond Spreads
Percentage point difference to generic German bond yield, daily



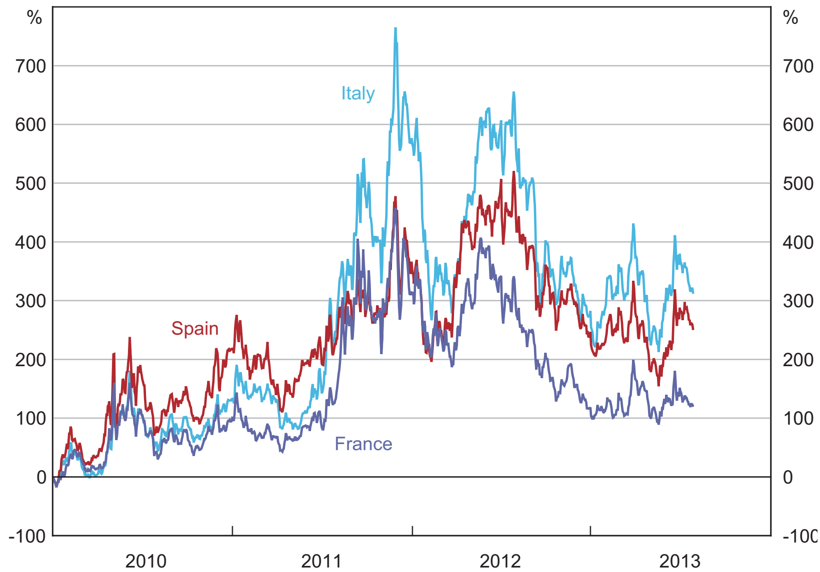
Notes: LTRO denotes long-term refinancing operations; due to data limitations, 8-year generic bond is used for Ireland

Sources: Bank of Canada; Haver Analytics

This stress in the core funding markets for peripheral sovereigns was reinforced by a concurrent deterioration in funding markets for peripheral banks as counterparty risk concerns emerged (Figure 14).

Figure 14: Bank CDS

Cumulative percentage change since 4 January 2010, daily



Notes: Custom index based on market capitalisation; France is based on Crédit Agricole, BNP and Société Générale, Italy is based on Intesa Sanpaolo and UniCredit, Spain is based on BBVA and Banco Santander

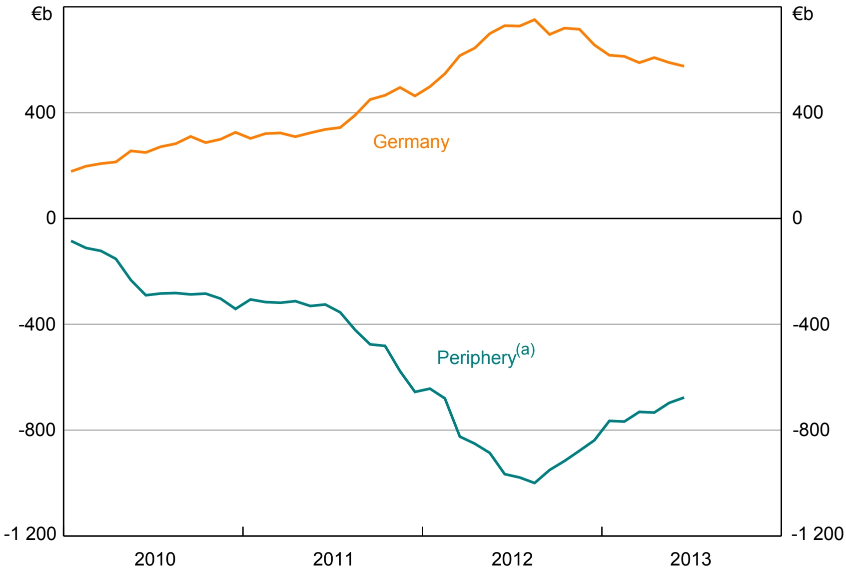
Source: Bloomberg

A negative feedback loop developed, in which impairment in the banking sector fed concerns about sovereign solvency. But as banks were major holders of sovereign debt, their balance sheets came under pressure. The results were twofold:

- Peripheral sovereigns were either shut out of their own 'core' funding markets and had to turn to the International Monetary Fund (IMF)/European Union (EU) for a program for financing, or were (eventually) implicitly backstopped by the establishment of the European Financial Stability Facility (EFSF)/European Stability Mechanism (ESM) and the ECB's Securities Markets Programme (SMP)/Outright Monetary Transactions (OMT).
- Peripheral banks were effectively shut out of the core unsecured funding market, and instead had to rely heavily on the lending facilities of the ECB, as seen in TARGET2 imbalances (Figure 15).

As funding dried up, credit to the private sector was significantly impaired – this in turn contributed significantly to the recession that began occurring in the euro area in the fourth quarter of 2011. Moreover, the run on core funding markets in the euro area – specifically sovereign and bank funding markets – even sparked concerns about the integrity of the euro area itself, further undermining confidence. While subsequent measures, such as the OMT and progress towards the banking union, have effectively reduced this risk, core funding markets had not yet returned to 'normal'.

Figure 15: TARGET2 Balances



Note: (a) Includes Greece, Ireland, Italy, Portugal and Spain
Source: Haver Analytics

6. Central Bank Support of Core Funding Markets

As discussed above, the recent crisis has clearly shown that financial markets, including those that we would define as core funding markets, are vulnerable to runs. These runs are triggered by large, systemic shocks, and manifest themselves as a severe lack of liquidity in which, at the extreme, markets freeze altogether as participants are unwilling to transact with each other at any price. Simply, the private sector generation of funding liquidity shuts down.

Liquidity shortages can be broken down into three distinct categories (Cecchetti and Disyatat 2010).

- The first is a shortage of central bank liquidity, in which specific institutions find themselves short of central bank reserve balances. This can be due to either a distributional problem within the system or an aggregate shortage of central bank reserves (due to, for example, a sudden increase in demand for central bank money for precautionary purposes). In either case, this liquidity shortage manifests itself through upward pressure in the overnight interest rate, with generally little risk that the dislocation spreads to other markets. This is the most benign type of liquidity shock, and can generally be addressed using standard OMOs.
- The second is an institution-specific shortage of funding liquidity. This is generally associated with idiosyncratic, counterparty-specific solvency concerns. These are best dealt with using institution-specific (as opposed to market-wide) support.
- The third, and most relevant for this paper, is a system-wide shortage of funding liquidity. A shortage of funding liquidity of this nature typically arises from a negative shock to confidence among market participants. Such a shock to confidence is generally due to incomplete or asymmetric information, either with regard to asset valuations or counterparty

creditworthiness. Such uncertainty can lead to a break down across a number of key markets, including those defined as core funding markets. The result is a collapse in the private sector generation of funding liquidity.

It is the third type of liquidity shortage that is the most disruptive to the broader financial system (and, by extension, the real economy). Funding liquidity is critical to the efficient and stable functioning of the financial system as a whole, including the effective transmission of monetary policy. As such, disruptions in core funding markets have material consequences for the real economy. Given central banks' price stability objectives, as well as their responsibilities to support the safety and efficiency of the financial system, they clearly should have an interest in ensuring that these markets function continuously, especially in times of stress. As the ultimate provider of domestic liquidity to their respective financial systems, central banks are uniquely placed to support these markets during times of extreme stress. This means that, when the private generation of funding liquidity shuts down, central banks should be prepared to extend their lender of last resort role to key funding markets, even becoming a 'market-maker of last resort' if required (Carney 2008a).

There are a number of problems that can lead to vulnerabilities in core funding markets, potentially leading to a system-wide funding liquidity shock. The first is incomplete or asymmetric information about counterparty credit risk, asset valuations, or both. The resulting increase in uncertainty often leads to a sharp increase in risk aversion on the part of the private sector participants, a reduced amount of trading activity, and an associated decline in liquidity. The second is weak market infrastructure. Poorly designed or fragile market infrastructure can actually magnify risk when the system is placed under stress. Consider, for example, a highly interconnected OTC derivative network with insufficient margining practices. Stress in one institution can quickly magnify and be transmitted to the entire system. Finally, a weak or inappropriate regulatory regime, including capitalisation levels that are too low, can significantly undermine the stability of core funding markets.

Given the nature of these problems, policies to strengthen and support the private generation of liquidity in core funding markets can take a number of forms.

- **Improvements in market infrastructure.** These policies can take two main forms. The first is the promotion of sound and robust clearing and settlement processes, including the creation of central counterparties (CCPs) where appropriate. Robust and risk-proofed CCPs can greatly diminish the risk that weakness in one participant in a core market will magnify and transmit to other participants. The second is the creation and support of more standardised and transparent financial instruments. Product standardisation and increased transparency reduces information asymmetry surrounding asset valuations, which should help support liquidity during times of stress.
- **Strengthening the regulatory framework.** Improvements in the current regulatory framework, both for the banking and shadow banking sectors of the economy, can reduce the incentives for inappropriate risk-taking, increase transparency as to the financial strength of counterparties, and ensure that market participants hold a sufficient degree of liquidity. Improvements in accounting standards can ensure that all participants have access to an appropriate level of information on their counterparties, while reducing mechanistic

reliance of credit rating agencies can foster a wider range of analysis and opinions on credit conditions.

- **Increasing the capitalisation of key market participants.** The increased capital charges resulting from the Basel II.5 and Basel III frameworks will result in better capitalised, more stable financial market participants. The associated decline in counterparty risk should have a material impact on reducing counterparty credit concerns and supporting the core funding markets.

These changes, all of which are currently in various stages of implementation, will enhance the resilience of the private generation of liquidity in core funding markets during times of stress. Nonetheless, even upon the successful implementation of all of these structural changes, there still may be times when relying solely on the private sector provision of funding liquidity is insufficient. A large shock to the financial system could still generate an aggregate demand for liquidity that is greater than the capacity of the private financial system to generate endogenously. It is in these circumstances that it would be necessary for a central bank to intervene, supporting those core funding markets that are not functioning properly and ensuring the sufficient provision of system-wide funding liquidity. The nature of this liquidity provision should, however, depend on the nature of the shock that has hit the financial system.

A central bank has three types of tools that it can use to support core funding markets (Cecchetti and Disyatat 2010).

1. **Direct lending to financial institutions.** This approach is appropriate when a single financial institution is facing a liquidity shock. Providing funding support to the institution can prevent an idiosyncratic shock from becoming a systemic one. If the liquidity shock is a shortage of central bank liquidity, this assistance is generally provided through standing facilities (e.g. the Bank of Canada's Standing Liquidity Facility). In the event there is a chronic shortage of funding liquidity for a specific institution, however, this form of central bank support is generally provided by facilities such as Emergency Lending Assistance (Canada) or Emergency Liquidity Assistance (euro area and the United Kingdom). This is one of the traditional lender-of-last-resort roles played by central banks. It focuses on specific institutions rather than markets, and will not be addressed further in this paper.
2. **Lending or borrowing in the open market.** This type of intervention is conducted through either repo-type operations (pledging of securities for cash) or securities lending (pledging less-liquid securities for more-liquid securities) and can be used to change the distribution of liquidity within the financial system when the private sector allocation of liquidity is no longer efficient. Private sector institutions may exit repo funding markets due to concerns (or lack of information) regarding either the creditworthiness of their counterparties or the valuation of the underlying collateral. Exit can either be complete (refusal to transact with a given counterparty or using a certain type of collateral) or partial (sharp increases in the haircuts applied to collateral values, even for high-quality assets). These types of operations provide liquidity enhancement or liquidity transformation services to the market – the central bank takes liquidity risk on its balance sheet by replacing liquidity-impaired assets in the private sector with unquestionably liquid assets (generally cash or government securities). The central bank is uniquely placed to perform this service in times of stress, as it is the only market participant that cannot face liquidity constraints.

3. **Outright purchases and sales of assets.** This type of intervention is used by some central banks as a standard means of implementing monetary policy through adjustments in the aggregate level of liquidity in the market.[4] In the context of this paper, however, we refer to the financial stability purposes in which the central bank may target quasi-permanent liquidity injections in specific markets as a means of encouraging the endogenous generation of liquidity. Operations for these purposes are generally more controversial than lending operations, as they (by design) have a direct impact on market prices. As well, they expose the central bank to a larger amount of risk. While lending/borrowing operations remove liquidity risk from the financial system, outright purchases and sales of assets remove either duration risk, credit risk, or FX risk (depending on the market targeted) from the private sector and place them on the central bank balance sheet.

The implementation of any of these tools raises moral hazard issues. It is likely, however, that such moral hazard concerns are less relevant for systemic liquidity shocks. These shocks represent a market failure that has been prompted by an aggregate liquidity shock that is not likely to be due to the assumption of broad-based government support by institutions or participants. Nevertheless, the market-wide fragilities that made the system vulnerable to such shocks in the first place may have been exacerbated by the failure of individual institutions to build up sufficient liquidity and capital buffers against such an event. This could be, in part, due to expectations of central bank support in times of crisis.

Given this, while central bank support of core funding markets during times of stress is necessary, the interventions should be structured so as to mitigate, as much as possible, the risk of any unintended consequences. The best way to accomplish this is to follow a structured, principled approach to implementation. Towards this end, the Bank of Canada has identified the following five principles that guide our provision of extraordinary liquidity and any interventions in core funding markets (Carney 2008b; Zorn, Wilkins and Engert 2009).

1. **Target those distortions of system-wide importance.** Interventions, particularly non-standard or exceptional measures, should be focused on system-wide disruptions of core markets. Central bank actions should not be used to mitigate or manage price volatility across non-core markets. As well, a central bank should only attempt to mitigate those market failures that it is best placed to rectify. Specifically, this means that interventions should generally be concentrated on liquidity disruptions, which central banks are best placed to address.
2. **Intervention should be graduated.** The strength and nature of the intervention should be commensurate with the breadth and magnitude of the disruption. Relatively minor liquidity dislocations can be addressed through the use of standard tools and the addition of liquidity through traditional channels (e.g. the provision of overnight liquidity through regular counterparties). As the severity of the stresses increases, the nature of the intervention should change accordingly. More widespread liquidity problems may warrant a more aggressive response. At the extreme, the breakdown of a core funding market may require direct intervention (market maker of last resort) by the central bank.

4 These operations typically involve purchases and sales of short-term government securities as a means of adjusting the aggregate level of central bank reserves.

3. **Intervention tools must be well designed.** Intervention programs should be carefully designed to address the specific market failure and focused on the specific core markets where the distortions are observed. For example, for some relatively minor market failures, the simple existence of a central bank backstop at a (slightly) penal rate may be sufficient to restart the endogenous liquidity generation process. If the issue is a shortage of high-quality collateral, on the other hand, the central bank may need to engage directly in collateral transformation operations. Finally, the most severe market disruptions are likely to require direct intervention.
4. **Minimise unintended market distortions.** By design, central bank interventions in core funding markets are intended to have a price and activity impact. Ideally, the intent is to get better alignment between actual market conditions with the price and activity level that would exist if the private sector generation of liquidity were functioning properly. Interventions should, however, be carefully designed to minimise any unintended effects beyond the initial goal. As a general rule, transactions should, to the extent possible, take place at market-determined prices and conditions. This can usually be facilitated through the use of an auction mechanism to allocate liquidity. In this way, the price of liquidity is determined by market participants and not by the central bank. Competitive auctions have another benefit – the simultaneous and anonymous participation of a wide range of participants in the operation can help minimise any stigma associated with the operation. As well, to the extent possible, facilities should be designed to preserve existing market structures. In many cases, this would mean using the traditional market makers as counterparties.
5. **Mitigate moral hazard.** Measures beyond those detailed above that could help mitigate the risk of moral hazard include the use of time-limited interventions, appropriate pricing and the promotion of sound supervision of liquidity risk management. The use of time-limited programs helps to ensure that market participants do not permanently change their behaviour. Appropriate pricing of operations can help ensure that central bank interventions have a natural and market-determined end date. While pricing must be cheaper than is available in the market at times of stress, it should be more expensive than market pricing during normal circumstances. In this way, the facilities become self-liquidating. Once market conditions improve, participants will automatically migrate away from the use of the intervention facilities. Sound supervision can help ensure that participants maintain (or build) appropriate liquidity risk management frameworks even in the presence of central bank interventions.

7. Case Studies: Three Central Bank Interventions

The global financial crisis provided a number of examples of central bank support of core funding markets. These operations had a broad range in terms of the markets they focused on, the market failure they were intended to address, their design and ultimate effectiveness. This section will review three operations, from three different central banks, targeting three distinct core funding markets, that were (or are) consistent with the criteria described above and have proven successful in addressing the market failure they were targeted at.

7.1 Canada: Term purchase and resale agreements

Driven by a combination of heightened funding pressures in other markets and a freeze in Canada's non-bank ABCP market, stresses in the short-term funding markets for Canadian banks began to mount significantly in the second half of 2007. The growing dislocation in these funding markets was evidenced by sharp increases in the costs of banks' short-term funding relative to the expected path of the overnight rate (as proxied by the CDOR-OIS spread).[5]

The initial widening in the CDOR-OIS spread, which took place in August 2007, was relatively minor, with the 3-month CDOR-OIS spread widened from a historical average of about 7 basis points to over 40 basis points. At that time, the Bank of Canada limited its market interventions to the use of the standard overnight facility (conducting special purchase and resale agreements (PRAs) and adjusting the level of settlement balances). This initially appeared to be sufficient, as bank funding spreads declined through October and November. The situation worsened going into year-end, however, and funding spreads began to widen. To address the renewed pressure, the Bank of Canada announced the term PRA facility, providing longer-term collateralised funding to a select group of market participants.[6]

The initial term PRA operations were relatively modest in size – consisting of two auctions of C$2 billion each and with maturities of less than one month (Figure 16). The operations were wound down in January 2008, and reinstated in March 2008 when funding pressures re-emerged. From March until May 2008, the Bank of Canada rolled 1-month operations, keeping the amount outstanding at C$4 billion, and let the facility wind down again by July as conditions improved.

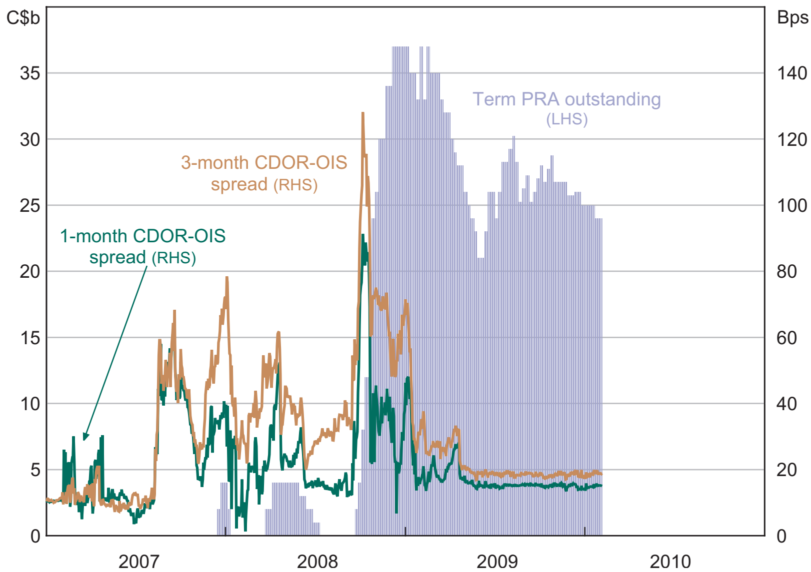
Funding conditions deteriorated very sharply in late 2008, with the 3-month CDOR-OIS spread reaching levels in excess of 120 basis points. Given that Canada had one of the most stable and well-capitalised banking systems in the world at the time, the fact that short-term funding pressures moved so sharply is indicative of the risks of contagion to the core funding markets. The Bank of Canada responded by materially expanding the scope of the term PRA operations. The size of the operations was materially increased (the maximum size reached C$12 billion), the frequency of operations was increased from biweekly to weekly, the range of eligible counterparties was expanded to include all primary dealers and all members of the domestic payment system, and the range of acceptable collateral was expanded. The outstanding amount of term PRA peaked at C$37 billion.

As shown in Figure 16, bank funding spreads declined fairly rapidly following this more aggressive implementation of the term PRA program. While care should be taken in attributing all of this improvement to the Bank of Canada's interventions, there is convincing evidence that term PRA announcements had both transitory and persistent effects on reducing the liquidity premium in bank funding costs (Enenajor, Sebastian and Witmer 2010).

5 CDOR stands for the Canadian Dealer Offered Rate and is the rate at which dealers will purchase BAs issued in the primary market. It can be seen as largely analogous to the LIBOR rate. OIS stands for the overnight indexed swap.

6 The term PRA operations were conducted exclusively with primary dealers for Government of Canada securities.

Figure 16: Term PRA Outstanding
Daily



Note: PRA denotes purchase and resale agreements
Sources: Bank of Canada; Bloomberg

The design and implementation of the term PRA facility over this period is judged, therefore, to have been a success. It is consistent with the five principles outlined in Section 6. It was designed to target distortions of system-wide importance (a sharp and broad-based increase in bank funding costs). Its implementation was graduated, becoming larger and more aggressive as the circumstances warranted. The interventions were also targeted directly at bank funding conditions, with minimal impact on other markets. Market distortions were minimised through the use of a competitive auction process for pricing – the allotment yield was determined by how aggressively the participating institutions bid. The Bank of Canada, therefore, was a price taker, not a price setter. Finally, steps were taken to mitigate the risk of moral hazard. As conditions improved, the Bank of Canada gradually reduced the size, term and frequency of the operations, halting operations on 12 April 2010.[7]

7.2 Central bank foreign exchange (FX) swap lines

A FX swap is the simultaneous purchase and sale of identical amounts of currency with two different value dates (a spot and forward transaction). For large banks with significant foreign currency assets, this market provides a critical means of accessing foreign currency funding. The *basis* represents the cost difference between borrowing in the domestic currency or using a

7 In early 2009, term PRAs began to be used as a monetary policy tool as well as a liquidity facility. Specifically, on 21 April 2009 the Bank of Canada lowered the target for the overnight rate to the effective lower bound (25 basis points) and made a commitment to keeping the overnight rate at this level until the second quarter of 2010, conditional on the outlook for inflation. To reinforce this commitment, the Bank of Canada conducted 6- and 12-month term PRAs with minimum and maximum bid rates set to the target (25 basis points) and the bank rate (50 basis points), respectively.

combination of borrowing in the foreign currency and using spot and FX forward transactions. Arbitrage should generally ensure that the basis stays relatively close to zero.

Prior to the crisis, a number of foreign banks (particularly European institutions) had built up large US dollar-denominated asset positions. While the funding of these positions came from a range of sources, the FX swap market represented one of the largest. As the crisis worsened, however, many of these banks began to have severe difficulties accessing the FX swap market. By late 2008, for example, the 3-month EUR/USD implied basis hit levels of approximately 300 basis points. This means that a European institution that could borrow at 3-month Euribor had to pay LIBOR plus 300 basis points to transform that into US dollar funding. Similar stresses were evident across other currency pairs (including JPY/USD and GBP/USD). For institutions with large amounts of US dollar assets that needed funding, this represented an extremely severe funding problem. To address this issue, the US Federal Reserve and a number of other central banks instituted central bank swap lines, whereby the Federal Reserve made US dollars available to other central banks (swapped in exchange for the participating central bank's domestic currency). The participating central banks, in turn, made the US dollars available to their domestic institutions that were facing US dollar funding shortages.

Usage of the central bank swap facilities peaked at almost US$600 billion (or roughly 25 per cent of the size of the Federal Reserve's balance sheet) in late 2008 and early 2009 before falling to zero in early 2010. Usage of the facility picked up again in late 2011 following the escalation of the European sovereign debt crisis. Evidence suggests that these reciprocal swap lines were successful in alleviating funding pressures in the FX market. Take-up by foreign institutions was very large and the announcement (and execution) of swap operations was associated with improved conditions in those markets. Empirical research generally supports this view (see, for example, Baba and Packer (2009) and Coffey *et al* (2009)).

Similar to the Bank of Canada's term PRA program, the design and implementation of the FX swap facilities can be viewed as a successful program to support a core funding market. It targeted distortions of system-wide importance. The program was graduated, starting off relatively small before expanding. The interventions were targeted; they focused exclusively on providing short-term US dollar funding (in exchange for foreign currency) to institutions that required it. Market distortions were minimised through a combination of the pricing mechanism (the swaps were priced below the rates that prevailed during stressed conditions, but well above normal market conditions) and the auction mechanisms that were used to allot the US dollars. Finally, the program was structured to minimise moral hazard. By being priced at a penalty rate relative to normal market conditions, the programs were self-liquidating. When conditions improved, the level of participation fell.

7.3 Outright Monetary Transactions (OMT) program

As the sovereign debt crisis in Europe escalated over the period of early 2010 to July 2012, a number of European sovereigns progressively lost market access. Greece effectively lost access to market funding in early 2010 and, by May 2010, euro area countries and the IMF agreed to a €110 billion aid package. Following this decision, the EFSF was created by the euro area member states. The EFSF's stated mandate was to safeguard financial stability in Europe by providing financial assistance to euro area member states. It was intended to provide a backstop to sovereign funding markets, providing financing to those vulnerable sovereigns who had lost market access under their own name. The EFSF was created as a temporary mechanism, and in December 2010 the European Council took the decision to create a permanent facility, the ESM. The ESM, which came into force in October 2012, serves as a funding backstop for euro area sovereigns. These facilities did not represent central bank support of a core funding market. Rather, they were a fiscal backstop, and their ability to raise and distribute funds is based on sovereign guarantees (EFSF) or paid-in capital (ESM). As such, they are limited in the amount of support they can provide.

Following the Greek package, pressure began to mount on other European sovereigns that were seen to be vulnerable. In November 2010, Ireland effectively lost market access and needed a funding package from the EU/IMF totalling €85 billion. In May 2011, Portugal received a €78 billion funding package. In each of these three cases, the resources of the EFSF (and ESM) were sufficient to guarantee that the sovereign would receive the necessary funding. Of more systemic concern was the potential loss of market access for Italy and/or Spain. As Spanish and Italian yields moved sharply higher in mid and late 2011, concerns that these sovereigns might lose market access escalated. The size of these sovereign bond markets meant that support from the EFSF/ESM would be insufficient. Only a central bank could provide sufficient support to guarantee funding access. This raised fears about a euro area exit and led to an increasing systemic risk (or re-denomination risk) component in European sovereign bond yields (Klose and Weigert 2012).[8]

The ECB did act – announcing two 3-year long-term refinancing operations (LTROs) in December 2011. These operations provided participating banks unlimited term financing (against acceptable collateral) and were designed to break the negative feedback loop between weak sovereigns and their banking system. While the LTROs were identified as a 'credit support measure to support bank lending and liquidity' (ECB 2011), there was a strong market expectation that they were also intended to help stabilise sovereign debt markets, particularly for Spain and Italy. In this regard, there was some initial success – there was a sharp initial decline in the yields on Spanish and Italian debt (by roughly 150 to 200 basis points). The effect was relatively short-lived, however. While LTROs offered banks funding certainty, which was a desirable outcome in its own right, *the design was not appropriate to serve as a direct backstop to sovereign funding markets*. The intervention tool was not designed to specifically and directly target the core market failure (a sovereign loss of market access), and did not minimise market distortions (Mullineux 2012). Rather than break the negative feedback loop between the sovereign and the banking system, it strengthened it by encouraging banks to access the LTRO and use the proceeds to purchase sovereign debt. Finally, there were moral hazard concerns in the sense that the program had no real conditionality; it provided funding to banks (and, indirectly, sovereigns) with no incentive for behavioural change.

Consequently, the improvement in sovereign funding conditions was short-lived. A number of European sovereigns (Spain and Italy in particular) saw their yields begin to move sharply higher once again. Fears grew that both Spain and Italy would require some sort of funding assistance.

The ECB response to these renewed stresses was the OMT. While not specifically identified, the notion of direct ECB support for sovereign funding markets was raised in a speech by Mario Draghi in 2012 (see Draghi (2012)). Specifically, Draghi said that

8 For an example of the increasing market concerns about redenomination, see Cameron (2012).

'[w]ithin our mandate, the ECB is ready to do whatever it takes to preserve the euro. And believe me, it will be enough'. While not providing specific details about the nature of the program, financial markets broadly interpreted this as a commitment that the ECB would support sovereign funding liquidity. The existence of a conditional ECB backstop was again raised at the 2 August 2012 ECB press conference and additional detail (including the name) around the OMT was provided in September 2012.

The impact of the OMT was significant. European sovereign bond yields began to fall immediately following the July speech. The outright level of yields, however, can be influenced by a variety of factors. More indicative of the success of the OMT was the decline in dispersion of government bond yields across euro area sovereigns (see Figures 17 and 18). This supports the hypothesis that country-level idiosyncratic risks (the 're-denomination risk' of exiting the euro area) began to play less of a role, while a common 'euro area' interest rate factor became relatively more important.

Figure 17: Dispersion of 2-year European Sovereign Bond Yields

Daily

Note: Shows the root mean squared error of the bond yields on individual European sovereign bonds compared with a GDP-weighted average euro bond yield

Sources: Bank of Canada; Bloomberg

Figure 18: Dispersion of 10-year European Sovereign Bond Yields
Daily

Note: Shows the root mean squared error of the bond yields on individual European sovereign bonds compared with a GDP-weighted average euro bond yield
Sources: Bank of Canada; Bloomberg

The OMT, while never actually having been activated, appears to have been successful at supporting euro area sovereigns' access to funding. As with the other programs reviewed, it is consistent with the five criteria discussed in this paper. It specifically targets a distortion of system-wide importance – sovereign funding markets. The intervention was graduated in the sense that the OMT followed a number of other programs (EFSF, ESM, LTROs) that were designed to address a more contained loss of sovereign funding access. Once it became clear that the problem was becoming increasingly widespread across the euro area, the OMT was introduced. The program was also well designed. It targeted the specific market failure directly and was of sufficient magnitude (essentially unlimited) that there was limited risk that the market could perceive the size of the program as insufficient. The OMT minimised unintended market distortions by remaining vague with regard to what it considered success. The objective of the OMT was never to bring the funding costs of all euro area sovereigns to a predetermined level (e.g. a very small spread to Germany), but rather to eliminate the yield premium that was associated with convertibility risk (the risk that the sovereign in question would re-denominate). As such, the market was uncertain as to what level the ECB saw as 'fair value' for a given sovereign (although it was generally assumed the fair value spread was significantly wider than the pre-crisis levels). Finally, the OMT took steps to mitigate moral hazard. Specifically, a necessary condition for an OMT intervention is the strict conditionality associated with an EFSF/ESM program (or a precautionary conditioned credit line). The presence of these conditions makes accessing the OMT a relatively unattractive option for a sovereign.

8. Conclusion

The preconditions for the global financial crisis and the subsequent global recession were established through the combination of a widespread increase in leverage, the ongoing growth in cross-border financing, and excessive risk-taking in an environment of inadequate regulation and supervision. The trigger was, however, a sharp decline in the value of US subprime mortgages and the associated securitised assets that held them. This led to a system-wide liquidity shock that spread to a range of funding markets. Funding liquidity vanished as a range of financial markets froze and it was only the timely and aggressive actions of authorities, including central banks, that prevented the near-total collapse of the financial system.

While the propagation of such a massive liquidity shock to the broad financial system would have significant effects on the real economy, there is a subset of funding markets that lie at the centre of the financial system and for which such a shock could have catastrophic consequences. These core funding markets are critical to the generation of liquidity within the financial system. The Bank of Canada has identified five such markets – sovereign debt, the repo market, securities lending, unsecured short-term bank debt and foreign exchange. These markets have no substitutes and, as such, they need to be continuously open.

A key lesson from the financial crisis is that, while these core funding markets need to be continuously open, they can be subject to runs if hit by a system-wide shock of sufficient magnitude. In these cases, the central bank must be prepared, under the appropriate conditions, to expand its lender-of-last-resort duties to support these markets. This support can come from a wide range of programs, including standing facilities, liquidity backstops, and direct market interventions. While the specific details of the support mechanism are dependent on the particular circumstances, effective central bank support of core funding markets should be targeted, graduated and well designed. The programs should be structured in such a way as to minimise market distortions, mitigate moral hazard and protect taxpayer resources. These principles will help the programs achieve their desired goals and minimise the chances of unintended consequences. There were a number of such programs undertaken by central banks over the crisis, with varying degrees of success. The more successful ones, however, all met the criteria outlined above.

The crisis has clearly shown that, given the growth and importance of market-based financing, central bank support of the core funding markets needs to be permanently available (although not permanently active). Authorities (including central banks), therefore, must take a more system-wide approach to monitoring, assessing and addressing vulnerabilities within the global financial system, both in traditional banking and shadow banking activities. The lender-of-last-resort function needs to be expanded to include support of core funding markets, with the central bank being a 'market maker' of last resort if necessary. The responses in the height of the crisis were by necessity *ad hoc*. Central banks should, however, take advantage of the lessons of the crisis to structure appropriate programs for the future. This entails identifying which markets are core for each jurisdiction, establishing monitoring and assessment capabilities to identify when those markets are under significant stress, and structuring effective support programs that minimise the likelihood of unintended consequences.

References

Baba N and F Packer (2009), 'From Turmoil to Crisis: Dislocations in the FX Swap Market Before and After the Failure of Lehman Brothers', BIS Working Paper No 285.

Bernanke BS (2005), 'The Global Saving Glut and the U.S. Current Account Deficit', Remarks at the William A Sandridge Lecture at the Virginia Association of Economists 32nd Annual Meeting, Richmond, 10 March.

Bernanke BS (2011), 'International Capital Flows and the Returns to Safe Assets in the United States, 2003-2007', Banque de France *Financial Stability Review*, 15, pp 13–26.

Brunnermeier MK (2009), 'Deciphering the Liquidity and Credit Crunch 2007-2008', *The Journal of Economic Perspectives*, 23(1), pp 77–100.

Brunnermeier MK and LH Pederson (2009), 'Market Liquidity and Funding Liquidity', *The Review of Financial Studies*, 22(6), pp 2201–2238.

Cameron M (2012), 'Dealers Tackle Euro Redenomination Risks', Risk online, 6 February. Available at <http://www.risk.net/risk-magazine/feature/2141921/dealers-tackle-euro-redenomination-risks>.

Carney M (2008a), 'Building Continuous Markets', Remarks to the Canada-United Kingdom Chamber of Commerce, London, 19 November.

Carney M (2008b), 'Principles for Liquid Markets', Remarks to the New York Association for Business Economics, New York, 22 May.

Carney M (2011), 'Global Imbalances: The International Monetary System and Financial Stability', Banque de France *Financial Stability Review*, 15, pp 31–38.

Cecchetti SG and P Disyatat (2010), 'Central Bank Tools and Liquidity Shortages', Federal Reserve Bank of New York *Economic Policy Review*, 16(1), Special Issue: Central Bank Liquidity Tools and Perspectives on Regulatory Reform, pp 29–42.

Cecchetti SG, MS Mohanty and F Zampolli (2011), 'The Real Effects of Debt', BIS Working Paper No 352.

Coffey N, WB Hrung, H-L Nguyen and A Sarkar (2009), 'The Global Financial Crisis and Offshore Dollar Markets', Federal Reserve Bank of New York *Current Issues in Economics and Finance*, 15(6), pp 1–7.

Copeland A, A Martin and M Walker (2011), 'Repo Runs: Evidence from the Tri-Party Repo Market', Federal Reserve Bank of New York Staff Report 506, rev March 2012.

Draghi M (2012), 'Verbatim of the Remarks made by Mario Draghi', Speech given at the Global Investment Conference, London, 26 July.

ECB (European Central Bank) (2011), 'ECB Announces Measures to Support Bank Lending and Money Market Activity', Press Release, 8 December.

Enenajor E, A Sebastian and J Witmer (2010), 'An Assessment of the Bank of Canada's Term PRA Facility', Bank of Canada Working Paper 2010-20.

Fontaine J-S, J Selody and C Wilkins (2009), 'Improving the Resilience of Core Funding Markets', Bank of Canada *Financial System Review*, December, pp 41–46.

FSB (Financial Stability Board) (2012), 'Global Shadow Banking Monitoring Report 2012', 18 November.

Gorton GB (2009), 'Information, Liquidity, and the (Ongoing) Panic of 2007', *The American Economic Review*, 99(2), pp 567–572.

Gorton GB and A Metrick (2009), 'Securitized Banking and the Run on Repo', NBER Working Paper No 15223.

Gravelle T, T Grieder and S Lavoie (2013), 'Monitoring and Assessing Risks in Canada's Shadow Banking Sector', Bank of Canada *Financial System Review*, June, pp 55–63.

Jaffee D, AW Lynch, M Richardson and S Van Nieuwerburgh (2009), 'Mortgage Origination and Securitization in the Financial Crisis', in VV Acharya and M Richardson (eds), *Restoring Financial Stability: How to Repair a Failed System*, John Wiley & Sons Inc, Hoboken, pp 61–82.

Klose J and B Weigert (2012), 'Determinants of Sovereign Yield Spreads During the Euro-Crisis – Fundamental Factors Versus Systemic Risk', German Council of Economic Experts Working Paper 07/2012.

McGuire P and G von Peter (2009), 'The US Dollar Shortage in Global Banking and the International Policy Response', BIS Working Paper No 291.

Mullineux A (2012), 'The Eurozone Crisis: Escaping the "Doom Loop"', unpublished manuscript, University of Birmingham, November.

Obstfeld M and K Rogoff (2010), 'Global Imbalances and the Financial Crisis: Products of Common Causes,' in R Glick and MM Spiegel (eds), *Asia and the Global Financial Crisis*, Asia Economic Policy Conference sponsored by the Federal Reserve Bank of San Francisco, San Francisco, pp 131–172.

Zorn L, C Wilkins and W Engert (2009), 'Bank of Canada Liquidity Actions in Response to the Financial Market Turmoil', *Bank of Canada Review*, Autumn, pp 3–22.

Discussion

1. Matthew Boge*

The paper by Grahame Johnson and Eric Santor raises the issue of what role a central bank should have within 'core' funding markets. In doing so, it recognises that this may involve more than just transacting in financial assets. It may also encompass regulatory policy and infrastructure development; in the Canadian case, for example, the promotion of a central counterparty for repos. However, the focus of the paper is very much on how a central bank's unique capacity to provide liquidity should best be deployed within these core markets to keep them open.

To this end, the Bank of Canada has developed a framework for thinking about when intervention may be warranted and the principles under which it is conducted.

The authors style such intervention as an extension of the central bank's lender-of-last-resort function. This might imply that the degree of market dysfunction is such that participants ordinarily reliant on it for liquidity are unable to procure it. Whether that is true may not always be easy to tell in practice. Elevated spreads may still be consistent with the market clearing, and the case for intervention might involve a more subjective assessment.

Either way, whether the market has broken down or whether liquidity premia are simply deemed to be excessive, central bank intervention can be rationalised as correcting a market failure, and the generally understood reasons for such failure are mentioned in the paper.

Consistent with the idea that central bank intervention is of the last resort, the paper stresses that interventions in core markets are best designed to be self-liquidating; that is, priced so that when market pressures abate, the demand for central bank funding disappears.

This raises the question of whether the programs themselves should be discontinued or whether the arrangements could simply be left in place during periods of normalcy. In the same way that a regular central bank standing facility may only be infrequently used, but is always in place to address institution-specific needs, facilities designed to address market-wide, systemic problems could be left in place and would trigger participation only when needed, assuming that the cost of access is, as suggested in the paper, set above market levels that would pertain during normal times.

For some, such permanency might raise the spectre of moral hazard, an issue that is never far away when discussing this topic. A more likely problem with sustaining the sort of programs discussed in the paper is that, by pre-committing the central bank to moderating movements in market prices, it would remove some of the central bank's flexibility. In this regard, perhaps the appropriate course is, as the Bank of Canada has done, to simply articulate the principles that will guide such intervention, rather than foreshadow the precise mechanics that would be applied in any given situation.

* The views expressed are those of the author and do not necessarily reflect those of the Reserve Bank of Australia.

However, while central banks have tended to close down many of the special programs and facilities introduced during the financial crisis (when market conditions have permitted), for many central banks, there will be elements of such interventions permanently in place within their operating frameworks.

A central bank that has as its operational target a short-term interbank rate will generally look to the private sector to establish the appropriate relativities between this rate and the yields on other financial assets. For this reason, central bank operations may be concentrated in the most liquid 'core' markets – such as the repo market for government bonds – where central bank activity is less likely to alter the relativity with the operational target.[1]

That is the case for Australia, but only superficially. While most of the Reserve Bank's transactions in the domestic market are indeed in repos involving government bonds, the range of securities eligible for the Bank's repurchase transactions has long been broader than this and, to the extent that it was widened further during the financial crisis, those changes, for the most part, were made permanent.

Combined with the wide range of counterparties eligible to participate in the Bank's routine operations and the ability of these counterparties to nominate the preferred maturity of their transactions, the equivalent of the Bank of Canada's term purchase and resale agreements was largely automated within the Australian context. That is, the Reserve Bank does not necessarily need to introduce a special facility to provide this type of funding; to a large extent, it can happen spontaneously within the Bank's routine market operations.

Can this approach be reconciled with the five principles for intervention as set out in the paper? Mostly, I would think that it could. Certainly, it is consistent with the idea that intervention should be graduated. As liquidity premia on eligible securities change, counterparties have the opportunity to alter the composition of the central bank's portfolio by delivering what are now the 'cheapest-to-deliver' securities, on both new and outstanding transactions. However, absent deliberate central bank action, increasing the size of these asset holdings further would only be automated to the extent that an expanded central bank balance sheet was needed to maintain the operational target.

Does this approach meet the principle of minimising unintended market distortions? In thinking about this, it should be acknowledged that eligibility for central bank operations can reduce the liquidity premia attached to securities and the effect is no doubt greater where eligibility pertains to routine market operations rather than just a standing facility, or where eligibility effectively classes an asset as liquid for prudential purposes, as will be the case in Australia under Basel III. In other words, the dividing line between eligible and ineligible assets can be of some significance. In this sense, a framework that seeks to ensure that bank funding can be sustained in a stressed period may have some impact on non-core markets (namely, the markets for potential bank assets). This is largely unavoidable in Australia and is something we have been conscious of in trying to accommodate a regulatory standard that requires banks to hold many more liquid securities than actually exist in the market.

1 In some cases, such as for the Bank of Canada, the operational target is the general collateral repo rate for government securities.

The paper provides examples of where central bank intervention had the desired effect on core markets. Thinking about why these interventions might have been successful raises some issues about the nature of liquidity provision by central banks.

The success of the central bank foreign exchange (FX) swap lines is easy enough to understand. Central banks (having accessed US dollars from the Federal Reserve) were able to provide US dollars to market participants in much the same form as that of the impaired 'core' market; either secured against local currency (as in an FX swap) or against local currency-denominated securities. While not every user of FX swaps would have had access to these operations, the breadth of eligible counterparties was such that the central banks were effectively acting as market makers in the impaired market.

The reasons why central bank intervention succeeded in driving down rates on short-term unsecured bank funding are perhaps less straightforward. Indeed, the authors are understandably cautious in not necessarily attributing all of the improvement to the actions of the central bank. Here, the intervention was not directly in the core market – such as in the form of outright purchases of unsecured bank debt – but was via collateralised funding. Why did this work?

In Australia's case, the equivalent operations involved contracting repos with counterparties (both banks and non-banks) against a list of eligible securities that included debt issued by banks. Hence, the success of these operations in moderating spreads on bank certificates of deposit (CDs) may have been partly because we were funding purchases of bank CDs by our counterparties. In that sense, providing funding liquidity was sufficient to encourage investors to remain in, or re-enter, the market, taking on the bank credit risk themselves. Alternatively, the successful outcome may have come about because the Reserve Bank was funding banks and allowing them to use comparatively illiquid assets as security for that funding (assets that could not have been directly funded otherwise), thereby limiting the need for them to issue CDs.

If the latter effect was more important, and I think that it was, this suggests that rather than supporting the 'core' market, the central bank effectively substituted for it. A similar interpretation could be made regarding the effect of the European Central Bank's (ECB's) long-term refinancing operations (LTRO). Granted, those operations didn't resolve the problems in the sovereign markets, as is noted in the paper. However, the LTRO did appear to assist bank funding. Nevertheless, I don't think it was by fostering the re-emergence of an active interbank market but, rather, by supplanting it.

It is also useful to consider central bank interventions that didn't work. As noted, the ECB's LTRO is characterised as being ultimately unsuccessful in the paper. One comment I would make about the ECB's experience is that I'm not sure that it is a good advertisement for a graduated response to market stresses, although I accept that others may simply view the preliminary responses as being misdirected, as the authors do.

In the Australian context, while we would characterise our operational changes as being generally successful, the positive effects were more pronounced in some areas than in others. In terms of the market near the heart of the financial crisis – namely, that for securitised assets – there was not much the Reserve Bank could do to revive that market. Making these securities eligible for the Bank's repo operations perhaps assisted their liquidity at the margin, but it did nothing to ease investor concerns about the credit quality of these assets.

While the securitisation market could not be considered 'core' in Australia (as funding the underlying assets on-balance sheet was an effective substitute for at least the larger players), this does perhaps highlight the limits to central bank intervention taking the form of acting as the 'market-maker of last resort', as it is phrased in the paper.[2]

2. General Discussion

Much of the discussion focused on the long-run objectives of central bank intervention in core funding markets. There was broad agreement among participants that central banks should intervene to keep core markets functioning. However, several participants suggested that policymakers had been too willing to fix problems that should never have occurred had markets been more structurally sound, and in doing so had allowed markets to return to sub-optimal pre-crisis equilibria. It was generally agreed that central bank intervention should be combined with structural reforms, including strengthening regulation, market infrastructure and the capital base, to reduce vulnerability to shocks in future. Grahame Johnson emphasised that even in the absence of structural problems, sufficiently large shocks to the system could motivate a role for central bank intervention. He also noted that conditionality in well-designed intervention programs should prevent a return to bad equilibria. The low credit risk premia on peripheral euro area countries' sovereign debt before the crisis was offered as an example of a bad pre-crisis equilibrium. In this context, Mr Johnson noted that neither the stated objective of the OMT program nor its realised effect had been to return spreads in peripheral countries to pre-crisis levels.

Another topic of discussion was motivated by one participant noting that the high level of wholesale market funding of financial institutions was often viewed as a potential source of instability. This raised the question of whether policymakers should be considering how to create a new steady state with a larger share of deposit funding. It was noted that there could be benefits from a higher share of deposit funding, since this source of funding had recently proven to be more sticky and less sensitive to banks' financial conditions. However, at the same time, the regulatory focus had been on making wholesale funding more stable by making debt 'bail-inable'. Having a wedge in the capital structure comprising wholesale debt that could convert to equity when needed, and was held by large sophisticated agents who understood the risks involved, could be preferable to the Cypriot experience where losses were imposed on depositors in the absence of alternatives.

This provoked debate about policymakers' apparent lack of willingness to haircut wholesale debtholders when risks crystallised. In contrast, it was noted that an important objective of current regulatory initiatives was to make wholesale debt more loss absorbing. Switzerland was cited as a jurisdiction in which banks had issued debt that could be written down if capital levels were to fall below stated thresholds. This observation was countered by the argument that the true

2 A more substantive intervention in the securitisation market was made by the Australian Government's debt management office – the Australian Office of Financial Management (AOFM). The AOFM undertook a program of *outright* purchases of residential mortgage-backed securities (RMBS). These purchases were targeted at those RMBS sponsored by (smaller) financial institutions that had less capacity to fund the mortgages on their balance sheets. While the AOFM's program no doubt assisted those firms and helped to provide a pricing benchmark for an illiquid market, it did not catalyse a more general revival in the market.

test of credibility was not in being able to issue such debt, but in whether the authorities had the will to follow through on such writedowns in the face of an adverse shock. Mr Johnson observed that one benefit of issuing contractual, rather than statutory, 'bail-inable' debt was that it should reduce the extent to which political pressure could undermine this credibility.

Another participant suggested that identifying foreign exchange spot and swap markets as core funding markets could give central banks more scope to intervene than might be appropriate. As an example, it was suggested that the decline in activity in the foreign exchange swap market during the financial crisis reflected a worldwide shortage of US dollar-denominated liquidity, rather than a disruption to market functioning that would warrant central bank intervention. Other participants argued that the foreign exchange spot market needed to function at all times, in the sense of exhibiting two-sided prices, and was therefore a core funding market. Mr Johnson noted that the Bank of Canada operated with a conditional commitment to take the other side of the market if the Canadian dollar market ever broke down by this measure.

A range of other observations were made. One participant asked whether the counterparties to the central bank in its interventions were afforded a competitive advantage; in such circumstances, the central bank would be expected to price funding more favourably than the prevailing market prices to enable the counterparty to profitably on-lend funds to other institutions. This raised the question as to how counterparties were selected. It was put forward that transactions should be limited to typical participants in the market to minimise market distortions. Another participant criticised the common approach of evaluating the success of non-standard monetary policy measures by assessing *ex post* market outcomes, claiming that since no counterfactual was observed, this was an incomplete analysis.

The Impact of Unconventional Monetary Policy on the Overnight Interbank Market

Morten L Bech and Cyril Monnet*

1. Introduction

The *modus operandi* of central banks in terms of implementing monetary policy has changed materially over the last six years since the start of the global financial crisis. Prior to the crisis, many central banks implemented monetary policy by specifying a target for the rate on unsecured loans of overnight funds between banks. The target rate in turn influenced other interest rates and hence financing conditions in the wider economy. The stance of monetary policy was loosened (tightened) by lowering (increasing) the target for the overnight rate. Central banks guided the overnight rate through a combination of open market operations and standing facilities where banks could either deposit or borrow funds (against collateral).

However, in response to the financial crisis and the ensuing economic downturn, central banks adapted monetary policy in unconventional ways.[1] Central banks provided liquidity backstops to many parts of the financial system and cut policy rates aggressively to their effective lower bounds. Some central banks now even provide explicit guidance on how long policy rates will stay low. Moreover, several major central banks embarked on large-scale asset purchase programs or very long-term refinancing operations with a view to reducing either term premia or liquidity risk. Both types of measures significantly expanded central bank balance sheets.[2] Furthermore, many central banks loosened the collateral requirements in their funding operations while others began subsidising the funding costs of financial firms with a view to boosting credit availability to the real economy.

Yet, the current state of affairs is temporary and central banks will – sooner or later – exit from their current extraordinarily accommodative polices.[3] But where will they exit to in terms of monetary policy implementation (Cœuré 2013b)?

The unsecured money market showed an unexpected degree of fragility during the financial crisis. Lending at longer tenors all but disappeared and the reference rate setting process was shown to be faulty. The large amount of reserves pumped into the banking system by unconventional policies has further affected stressed market dynamics. To the extent that resilience has not

* The views expressed in this paper are those of the authors and do not necessarily reflect those of the Bank for International Settlements.

1 Attempts at taxonomies are available in Borio and Disyatat (2010) and Stone, Fujita and Ishi (2011).

2 Since the end of 2007, central bank total assets have doubled to more than US$20 trillion, or just over 30 per cent of global GDP.

3 The Swedish central bank has already exited from the unconventional policy measures it implemented in response to the financial crisis.

improved and that the stressed conditions are not self-reversing, the unsecured overnight money market might not be the best choice as the first link in the chain of monetary policy transmission going forward. Moreover, the forthcoming implementation of global liquidity regulation also poses challenges for operational frameworks across jurisdictions (see Bech and Keister (2013)).

In other words, monetary policy implementation is at a crossroad and central banks are prudently exploring alternatives. For example, as noted by Stark (2011), a consequence of the financial crisis may be a move from unsecured to secured transactions in the interbank money market and this may trigger a similar move by central banks in terms of policy target.[4] In a similar vein, several members of the Federal Open Market Committee (FOMC) have raised the possibility that the federal funds rate might not, in the future, be the best indicator of the general level of short-term interest rates. They have also supported further staff study of potential alternative approaches to implementing monetary policy in the longer term and of possible new tools to improve control over short-term interest rates (FOMC 2013).

However, a challenge for devising alternative approaches is that the standard economic models for studying monetary policy implementation and the interbank market have some limitations. In particular, models of banks' reserve management in the tradition of Poole (1968), for example Woodford (2001), Bindseil (2004), Whitesell (2006) and Ennis and Keister (2008), focus solely on price (i.e. overnight rate) dynamics. Consequently, these models have little to say about quantity and liquidity dynamics, whose importance are now evident. Fortunately, a burgeoning amount of research is improving our understanding of the interbank money market, for example Afonso and Lagos (2012) and Bech and Monnet (2013). As interbank trading is explicitly included in these models, it is possible to discuss issues such as market structure, volume and liquidity. Moreover, as banks trade at different rates, these models also provide insights on intraday interest rate volatility.

In this paper, we start by documenting four stylised facts with respect to the impact of unconventional monetary policies on the price and quantity dynamics of the overnight money market. We look at six markets in developed economies. We show that the surge in excess reserves has driven overnight rates to the rate at which the central bank remunerates reserves. Furthermore, we illustrate how the expansion of excess reserves decreases market volume and reduces the volatility of the overnight rate. In addition, we provide *prima facie* evidence that counterparty risk affects the pricing of unsecured overnight loans between banks even when the market is flush with liquidity.

With the stylised facts in hand, we review the models in Poole (1968), Afonso and Lagos (2012) and Bech and Monnet (2013) within a common framework and compare how the predictions of the models stack up against the stylised facts. Based on the models, we find that the observed dynamics in the overnight money market are in line with what we would expect as a consequence of the observed market stresses and unconventional policies. Taken at face value, this suggests that once the unconventional policies and market stresses are reversed the unsecured overnight money market may, in fact, re-emerge and central banks will be able to resume their conventional *modus operandi*. There are a number of caveats to this assertion and we discuss them in the conclusion.

4 See also discussions in Cœuré (2013a, 2013b).

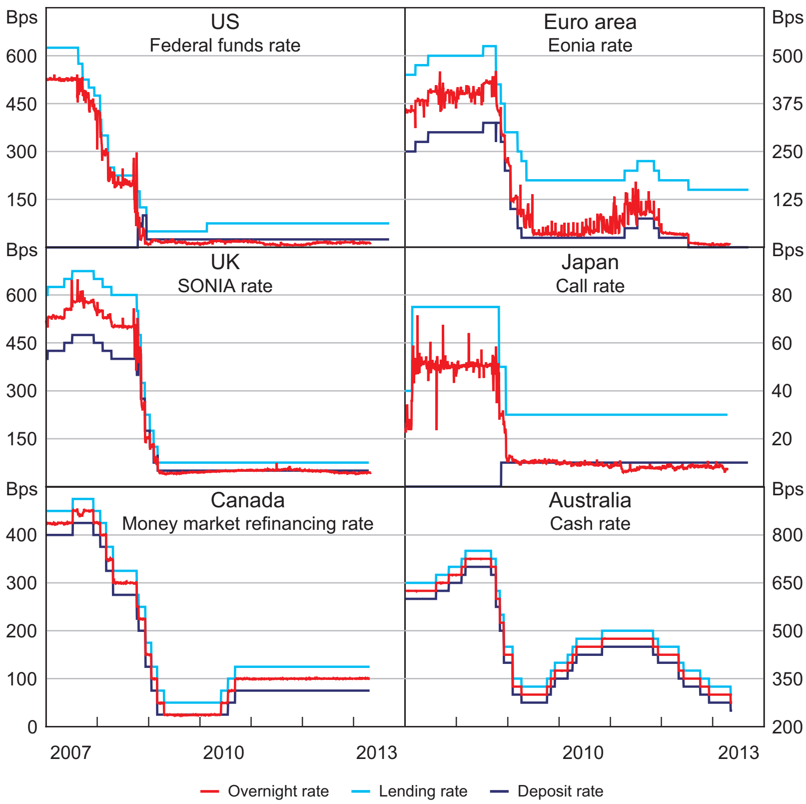
2. Stylised Facts

In this section, we document four stylised facts in terms of price and quantity dynamics in the overnight interbank market during the recent period of unconventional monetary policy. We focus on six markets in the developed world. The markets are the *federal funds* market for the US dollar, the *Eonia* market for the euro, the *call loan* market for the yen, the *SONIA* market for pound sterling and the overnight markets for Canadian and Australian dollars.[5]

The six panels of Figure 1 show the average overnight rate in each market – along with the prevailing rates at which banks could deposit or borrow funds from the central bank.

Figure 1: Overnight Rate and Standing Facilities

Daily



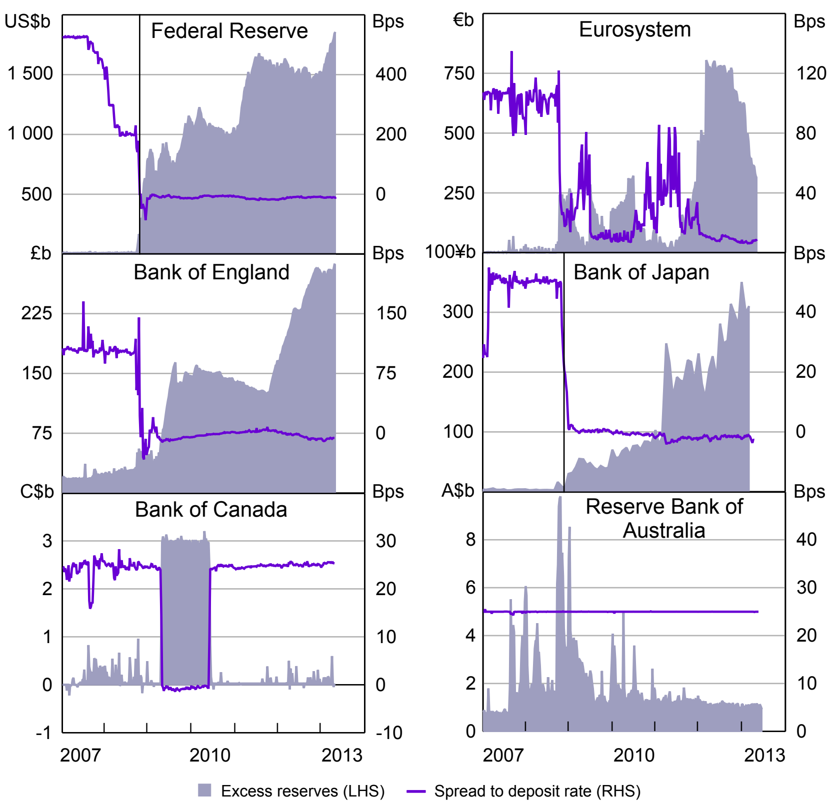
Sources: Thomson Reuters; national sources

The substantial cuts in policy rates that followed the onset of the financial crisis are evident across all markets and six years later overnight rates remain significantly below those of mid 2007. With the exception of Australia, overnight rates in all markets have flirted with the zero lower bound.

5 More information on the details of the different rates and markets are available in Appendix A.

In our sample, the Federal Reserve, the European Central Bank (ECB), the Bank of England, the Bank of Japan and the Bank of Canada have all implemented some form of unconventional policy measures and have seen a substantial increase in excess reserves as a result of liquidity backstops, asset purchases or very long-term refinancing operations (see Figure 2). In contrast, the Reserve Bank of Australia (RBA) has by and large relied on conventional policy measures. While the unconventional measures implemented differ across central banks and are likely to affect the overnight interbank market through different channels, we focus here solely on the increase in excess reserves. We conjecture that this is the most important channel. We see Australia as our 'control market' and the remainder as our 'treatment group'.

Figure 2: Excess Reserves and the Overnight Rate



Notes: For the Federal Reserve panel, the vertical line marks the date interest paid on reserves was introduced; for the Bank of Japan panel, the vertical line marks the date the complementary deposit facility was introduced

Sources: Thomson Reuters; national sources

The stylised facts are that a massive increase in the amount of excess reserves in the banking system: (1) drives the overnight rate to the floor of the corridor; (2) reduces the volatility of the overnight rate; and (3) decreases market volume. In addition, we present prima facie evidence of a fourth stylised fact that counterparty risk affects the pricing of unsecured overnight loans between banks.

2.1 Stylised fact 1: Overnight rate at the floor of the corridor

Since late 2008, all six central banks have remunerated excess reserves and hence have been operating using a so-called corridor system.[6] As noted by Woodford (2001, p 38), in a corridor system:[7]

> the demand for [overnight funds is] a function of the location of the overnight rate *relative* to the lending rate and deposit rate, but independent of the *absolute level* of any of these interest rates.

Hence, in addition to the amount of excess reserves, the panels of Figure 2 also plot the spread between the overnight rate and the central bank deposit rate. Within our treatment group this spread narrows as the amount of excess reserves increases. In particular, the spreads were compressed towards zero in jurisdictions where the amount of excess reserves surged. That is, the substantial increase in excess reserves drove overnight interbank rates towards the rate at which the central bank remunerates reserves, namely the floor of the corridor. Hence, these central banks abandoned their usual practice of keeping the overnight rate close to the midpoint of the corridor spanned by the standing facility rates. In contrast, Australia saw much smaller shifts in excess reserves and the RBA has been able to keep the cash rate at the centre of the 50 basis point wide corridor.

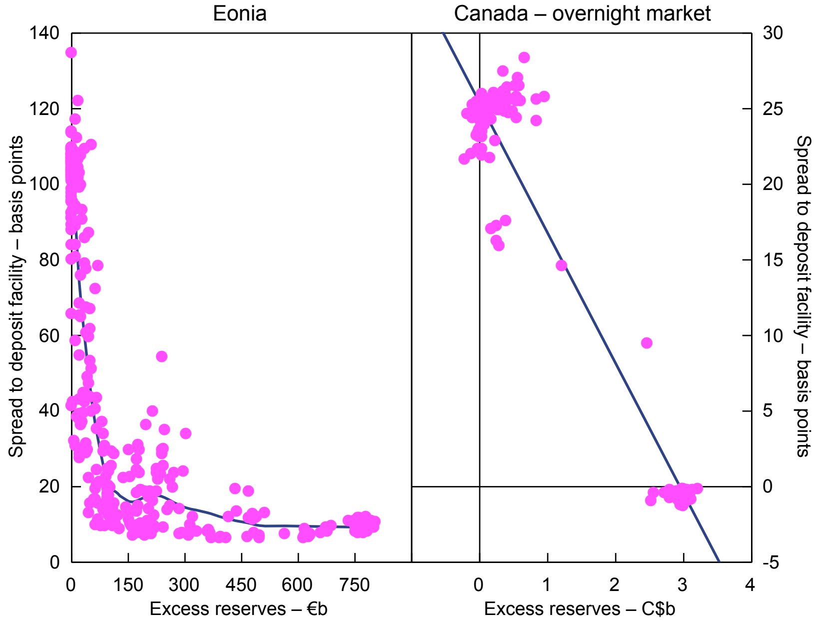
In some markets, the average overnight rate has moved below the deposit rate, that is, there is a negative spread to the deposit rate. This somewhat surprising outcome is due to a combination of market segmentation and limits to arbitrage. As discussed in Bech and Klee (2011), if not all market participants have access to the central bank deposit facility then the overnight market can bifurcate. If limits to arbitrage are severe enough, the disadvantaged participants may sell at lower rates. Hence, if their market share is sufficiently large, as a matter of simple arithmetic, the average overnight rate can print below the central bank deposit rate.

To highlight the inverse relationship between excess reserves and the overnight rate further, Figure 3 shows two scatter plots of excess reserves and the spread to the deposit facility rate for the Eonia and the Canadian overnight market (see also Zhang (2012)).

6 The Federal Reserve began to pay interest on depository institutions' required and excess reserve balances on 9 October 2008. The Bank of Japan began to pay interest on current account balances and special reserve account balances on 16 November 2008.

7 Berentsen and Monnet (2008) present a general equilibrium model of a corridor (or channel) system.

Figure 3: Excess Reserves and the Overnight Rate

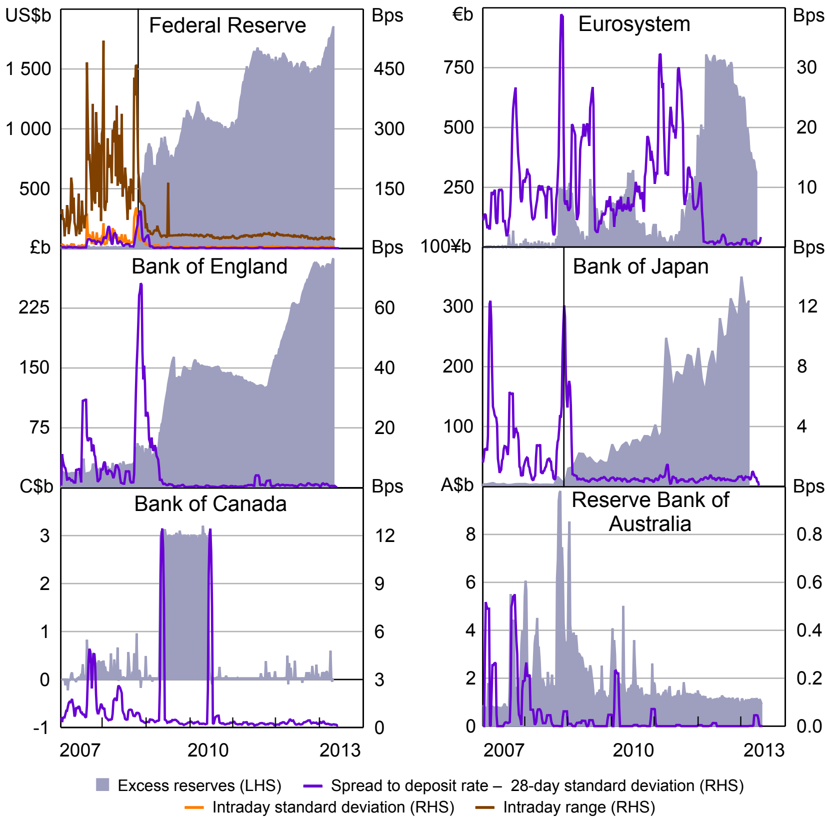


Sources: Bloomberg; Thomson Reuters; national sources

2.2 Stylised fact 2: Overnight rate volatility has decreased

In addition to pushing overnight rates to the floor of the corridor, the massive expansion of excess reserves has also tended to reduce the volatility of overnight rates. The panels in Figure 4 plot the amount of excess reserves together with the 28-day rolling standard deviation of the spread between the overnight rate and the central bank deposit rate.

Figure 4: Excess Reserves and the Overnight Rate
Weekly



Notes: For the Federal Reserve panel, the vertical line marks the date interest paid on reserves was introduced; for the Bank of Japan panel, the vertical line marks the date the complementary deposit facility was introduced

Sources: Thomson Reuters; national sources

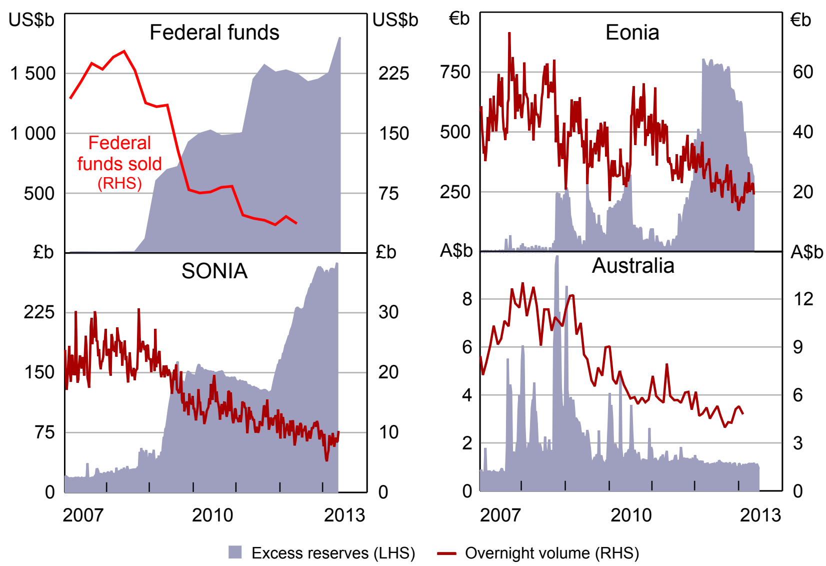
The panel for the Federal Reserve includes two measures of the intraday dispersion of transaction rates. Every day a number of brokers in the federal funds market submit to the Federal Reserve Bank of New York (FRBNY) the amount of the transactions they have brokered at different rates. Based on these data, the FRBNY determines not only the average federal funds rate plotted in Figure 4 but also the standard deviation of rates and the low and high rates of the day.

The panels in Figure 4 suggest that for central banks in the treatment group, overnight rate volatility decreased as central bank balance sheets expanded, while volatility in the Australian overnight market has remained fairly constant.

2.3 Stylised fact 3: The market volume has fallen

Figure 5 plots interbank market volume together with the amount of excess reserves for a number of markets. Unfortunately, volume information is not as readily available as information on the overnight rate. In fact, daily data are only publicly available for two of the six markets we consider here (Eonia and SONIA). To get a clearer picture of the impact of unconventional policies on market volume, we also look at quarterly market volume for the federal funds market and weekly information for the Australian overnight market.[8] The volume has fallen across all markets. For the Eonia and the federal funds market, the movement in volume broadly correlates with the movement in excess reserves. For the SONIA market the relationship in less pronounced but volumes have fallen significantly. For the Australian dollar market volume has fallen despite excess reserves being fairly constant over the period.

Figure 5: Excess Reserves and the Overnight Volume



Note: The data for overnight volume are quarterly for the United States, weekly for Australia, and weekly averages of daily data for the Eonia and SONIA markets

Sources: Bloomberg; Thomson Reuters; national sources

2.4 Stylised fact 4: Credit risk pushes up the overnight rate

The widening of interest rate spreads during the recent financial crisis represented both deteriorating liquidity and greater credit risk. Debelle (2008) describes the situation in the Australian money market at the outset of the financial turmoil as follows:

> Beginning in August 2007, as banks became less certain of their own funding requirements and less confident of the credit profile of their counterparties, the interbank borrowing markets became

8 The data for the federal funds market are from Kreicher, McCauley and McGuire (2013) and the data for the Australian market were provided by the Reserve Bank of Australia.

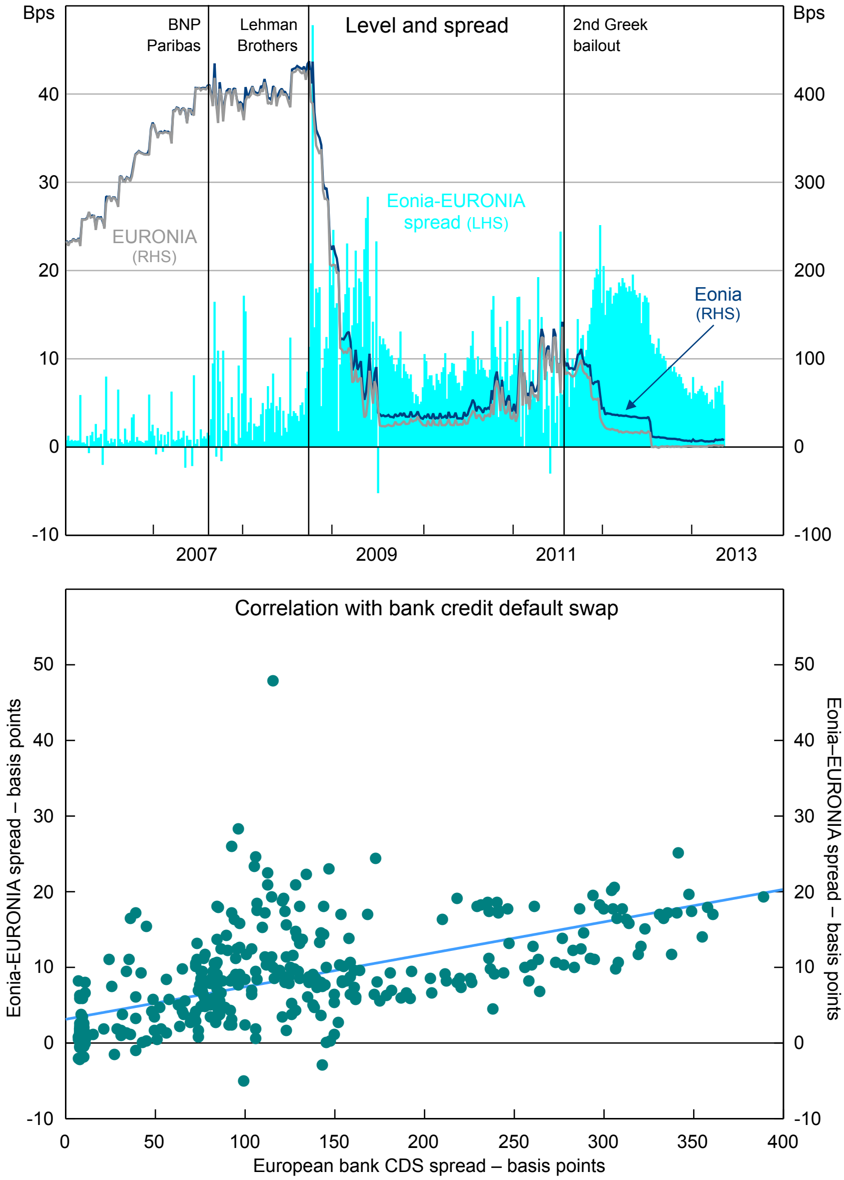
> quite tight. Banks were more inclined to hold onto cash, both because of an increased unwillingness to lend it, but also reflecting a concern about their ability to obtain funding themselves from the market in the future should they require it. This was most evident in term markets, where borrowing rates increased sharply. However, for similar reasons, there was an increased precautionary demand for [reserve] balances, reinforced by the fact that [reserves] are a risk-free asset. The effect was the demand curve for [reserves] shifted out.

A burgeoning literature seeks to disentangle the two effects, for example Michaud and Upper (2008), Taylor and Williams (2008, 2009), McAndrews, Sakar and Wang (2008), Christensen, Lopez and Rudebusch (2009), Heider, Hoerova and Holthausen (2009), Schwarz (2010) and Angelini, Nobili and Picillo (2011). However, with the banking system flush with excess reserves, liquidity hoarding is now likely to be less of an issue in the (overnight) interbank market but credit risk might still matter. Unfortunately, good measures of the impact of credit risk on overnight rates are hard to find.

One example – used by market analysts – is the spread between the Eonia and EURONIA rates (see, for example, Marraffino and Fransolet (2012)). The Eonia rate is a weighted average of all overnight unsecured lending transactions in the interbank market, undertaken by a panel of banks in the European Union and European Free Trade Association countries. In contrast, the EURONIA rate is the weighted average of all unsecured euro overnight cash transactions brokered in London by contributing members of the Wholesale Markets Brokers' Association. The number of participants is smaller in the EURONIA market and they are generally regarded as having been – on average – of higher creditworthiness than the participants in the Eonia market. Consequently, the spread between the two rates is thought to reflect primarily differences in credit risk.

The top panel of Figure 6 plots the Eonia and the EURONIA rates as well as the spread between them since 2006. Prior to the financial crisis, the difference was, on average, a couple of basis points. However, the spread moved up in August 2007 and climbed further in the aftermath of the Lehman Brothers bankruptcy in September 2008. It has remained elevated ever since and has generally followed the ebbs and flows of the perceived health of the European banks. The bottom panel in Figure 6 illustrates this point. It shows a scatter plot of a credit default swap index for European banks and the spread between Eonia and EURONIA rates. There is a clear positive correlation.

Figure 6: Credit Risk and Overnight Rates



Sources: Bloomberg; Thomson Reuters; national sources

3. Three Models of the Interbank Market

In this section, we review three models that all seek to explain essential elements of the overnight interbank market and monetary policy implementation. The first one is the standard model of monetary policy implementation in a corridor system, based on the seminal contribution of Poole (1968). Examples include Woodford (2001), Whitesell (2006) and Ennis and Keister (2008). The second model is the recent application of search theory to the interbank market in Afonso and Lagos (2012). The final contribution is the directed search model with credit risk presented in Bech and Monnet (2013). We recast the different models within a common framework to highlight both commonalities and differences and we compare the predictions of each model in light of the stylised facts presented above.

3.1 The basic set-up

All three models fit within the following basic set-up. There is a measure one of risk-neutral banks, indexed by *i*, each of which aims to maximise expected profits by adjusting reserve holdings, R_i. The banks enter the day with the same reserve holdings $R_i = R_0$ and are required to hold $\overline{R} \geq 0$ units of reserves at the end of the day.[9] We say that the banking system is in a (structural) liquidity surplus if $R_0 > \overline{R}$ and in a (structural) liquidity deficit if $R_0 < \overline{R}$. Liquidity conditions are neutral or balanced if $R_0 = \overline{R}$.

During the day the reserve positions of banks change as a result of payments executed and received on behalf of customers. The interbank payment system operates two sessions. The first session is for customer payments whereas the last session is reserved for settlement of interbank overnight loans.[10] The net inflow of reserves in the first session is given by v_i. The value of v_i is independent across banks and is drawn from a common symmetric distribution *F* defined over $[-\overline{v}, \overline{v}]$. Hence, once the interbank payment system closes for customer payments the reserve position of bank *i* is:

$$R_i = R_0 + v_i. \tag{1}$$

Thereafter, the interbank market opens. Here, banks trade overnight loans with each other to get closer to their desired end-of-day reserve position. Let Δ_i denote the (net) amount borrowed by bank *i*. If $\Delta_i < 0$ then bank *i* is a (net) lender. The reserve position of bank *i* after the interbank market closes is:

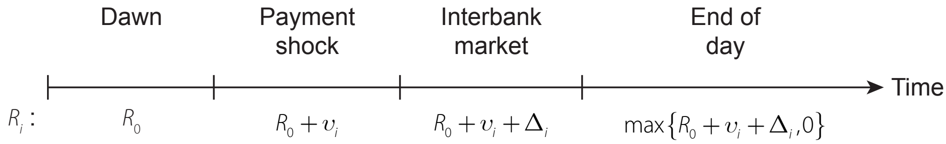
$$R_i = R_0 + v_i + \Delta_i. \tag{2}$$

If a bank is short of reserves at the close of business $\left(R_i < \overline{R}\right)$ then it borrows the shortfall from the central bank (against collateral), paying the penalty rate, r^p. On the other hand, if a bank is long $\left(R_i > \overline{R}\right)$ then it deposits the surplus with the central bank, earning the rate, r^d. Required reserves are remunerated at the same rate. The time line in Figure 7 summarises the basic set-up and the reserve position of bank *i* over the course of the day.

9 We ignore maintenance period dynamics for simplicity.

10 For example, TARGET2 – the Eurosystem real-time gross settlement (RTGS) system for payments in euros – closes for customer payment at 17:00 whereas interbank transfers can occur until 18:00. In the United States, the Federal Reserve's RTGS Fedwire closes for customer payments at 18:00 (Eastern Standard Time) and 18:30 for so-called Settlement Payment Orders.

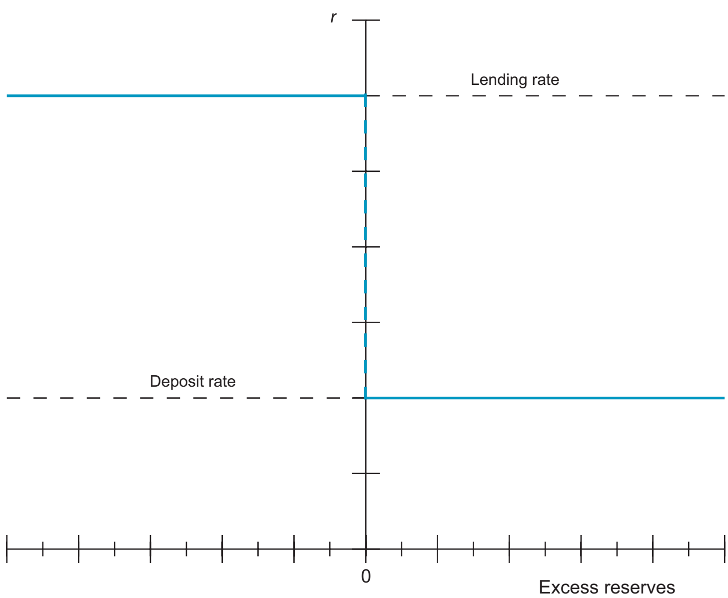
Figure 7: Time Line



As a benchmark for the analysis that follows, assume that the interbank market is *perfectly competitive*. That is, banks are price takers and they can trade any amount at the overnight rate, r^{Δ}. In equilibrium, banks will equate the marginal benefit of an extra dollar of reserves with the marginal cost of obtaining the dollar via an overnight loan, r^{Δ}.

If there is a system liquidity deficit, then the overnight rate – in equilibrium – is equal to the central bank deposit rate (r^d), whereas it is equal to the central bank lending rate (r^p) if there is a system liquidity surplus (see Figure 8). If liquidity conditions are balanced, the overnight rate is indeterminate – any rate between r^d and r^p is consistent with equilibrium (see, for example, Clinton (1997) and Borio and Disyatat (2010)).

Figure 8: Inverse Demand for Excess Reserves – Perfectly Competitive Market



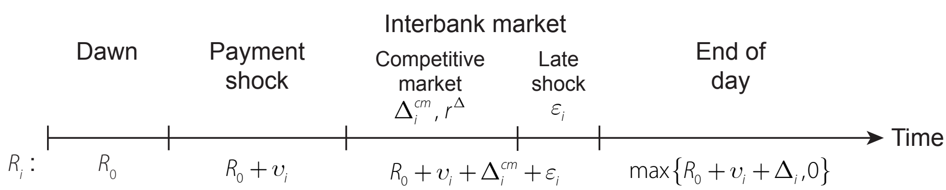
The three models we review here all start from the premise that the interbank market is imperfect. They differ, however, in terms of how they model the structure of the interbank market and the imperfections that prevent banks from perfectly targeting their end-of-day reserve balances.

The models in the tradition of Poole (1968) maintain the assumption that banks are price takers but deviate from perfect competition by introducing an aftermarket shock to reserve balances. Afonso and Lagos (2012) assume that the interbank market is an over-the-counter (OTC) market and that banks trade over multiple rounds with randomly selected counterparts. In Bech and Monnet (2013) the market structure is also OTC but banks use directed search to find counterparts in a way that resembles a brokered market. In addition, banks can default. We now describe the interbank market in each of the models.

3.2 Interbank market in Poole (1968)

In the Poole (1968) model, the interbank market is competitive. Banks are price takers and can trade any amount, Δ_i^{cm}, at the interbank rate, r^Δ, which clears the market. However, in order to capture market imperfections, the model introduces an additional shock to reserve holdings after trading halts in the interbank market. That is, each bank receives an aftermarket shock, $\varepsilon_i \sim G_\varepsilon$, to its reserve balance. This can, for example, be due to end-of-day settlements of auxiliary payment and security settlement systems. Hence, the total impact on the reserve holdings of a bank is $\Delta_i = \Delta_i^{cm} + \varepsilon_i$. The key assumption in Poole's model is that while banks can trade the early payment shock in the market, they cannot trade based on their late shock or insure against it before it hits. We summarise the Poole model via the time line in Figure 9.

Figure 9: Time Line – Poole Model



Banks seek to maximise their profit and there is no credit risk. Bank *i* chooses Δ_i^{cm} so as to equate the marginal cost with the expected marginal benefits, or:

$$r^\Delta = r^p\left[1 - G_\varepsilon\left(R_0 + \Delta_i^{cm} - \bar{R}\right)\right] + r^d G_\varepsilon\left(R_0 + \Delta_i^{cm} - \bar{R}\right) = r^d + \left(r^p - r^d\right)G_\varepsilon\left(-R_0 - \Delta_i^{cm} + \bar{R}\right). \quad (3)$$

In words, the value of an incremental increase in borrowing in the interbank market is the cost of paying back this loan, $-r^\Delta$. Also, the marginal value of a bank's account balance is the expected gain from having a positive account balance at the end of the day. If the late payment shock is not severe, the extra balance will be accounted for as excess reserves and will earn the interest rate r^d. Finally, if the late payment shock is severe enough, the incremental balance is used instead of having recourse to the discount window. This saves the bank r^d. We can rearrange Equation (3) to obtain the demand of bank *i* in the overnight market:

$$\Delta_i^{cm} = \bar{R} - R_0 + G_\varepsilon^{-1}\left(\frac{r^p - r^\Delta}{r^p - r^d}\right). \quad (4)$$

Given policy rates r^d and r^p, and aggregate balances R_0, an equilibrium is an overnight rate r^Δ such that Δ_i^{cm} solves Equation (4) for all *i* and the market clears, that is, $\int_i \Delta_i^{cm}\, di = 0$. Therefore, the equilibrium overnight rate satisfies:

$$r^{\Delta *} = r^p\left[1 - G_\varepsilon\left(R_0 - \bar{R}\right)\right] + r^d G_\varepsilon\left(R_0 - \bar{R}\right). \quad (5)$$

That is, $r^{\Delta*}$ is a weighted average of the policy rates r^d and r^p, where the weights depend on the aggregate balances. Therefore the interbank market rate is necessarily within the corridor defined by r^d and r^p, and it responds one for one with a shift in the corridor. Using the expression for the equilibrium overnight rate, $r^{\Delta*}$, we obtain the quantity traded by each bank:

$$\Delta_i^{cm} = R_0 - R_i = -\upsilon_i. \tag{6}$$

Hence, the aggregate volume is given by $Q = \int_i | - \upsilon_i| di$. We illustrate the model in the example below.

3.2.1 Numerical example

Let $r^d = 2\%$, $r^p = 4\%$, $\bar{R} = 0$, and $\varepsilon_i \sim N(0, \sigma_\varepsilon)$ then Equation (3) becomes

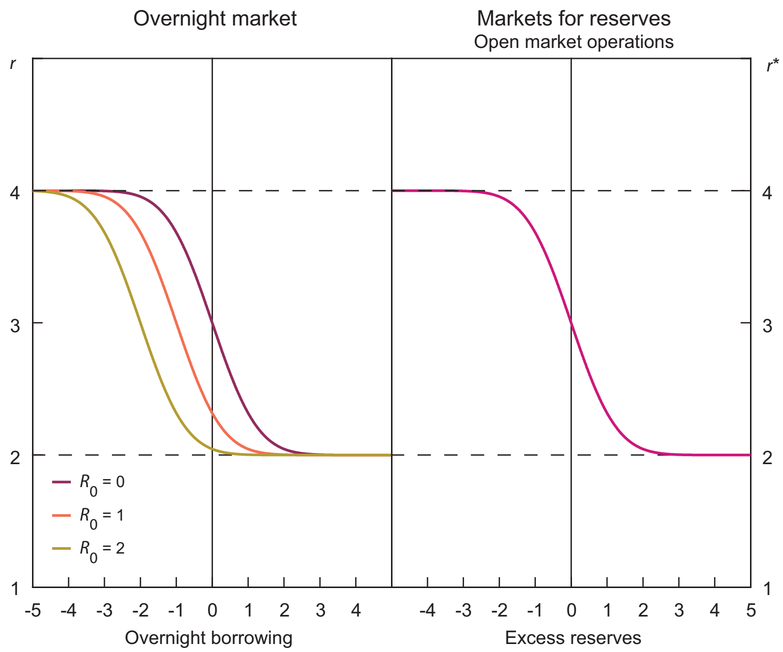
$$r(\Delta_i) = 2\% + 2\% \left(1 - \Phi\left[\frac{R_0 + \Delta_i^{cm}}{\sigma_\varepsilon}\right]\right), \tag{7}$$

where Φ is the cumulative standard normal distribution function. We plot Equation (7) in the left-hand panel of Figure 10 for three different levels of reserves $R_0 = \{0, 1, 2\}$ and $\sigma_\varepsilon = 1$. Intuitively, the inverse demand curve is decreasing and moves to the left as the amount of reserves increases. Since the market has to clear, the equilibrium interest rate is determined by setting $\Delta_i^{cm} = 0$ for each possible value of R_0 and finding the corresponding value of $r^{\Delta*}$ on the vertical axis. This relationship can be written as

$$r^*(R_0) = 2\% + 2\% \left(1 - \Phi\left[\frac{R_0}{\sigma_\varepsilon}\right]\right), \tag{8}$$

and is depicted in the right-hand panel of Figure 10.

Figure 10: Interest Rate in the Poole Model



If υ_i follows a normal distribution, then $|\upsilon_i|$ follows a half-normal distribution. Hence, the aggregate expected volume is given by:

$$E[Q] = \int_i E[|-\upsilon_i|]di = E[|-\upsilon_i|] = \sqrt{\frac{2}{\pi}}\sigma_\upsilon. \tag{9}$$

3.2.2 The Poole model and the stylised facts

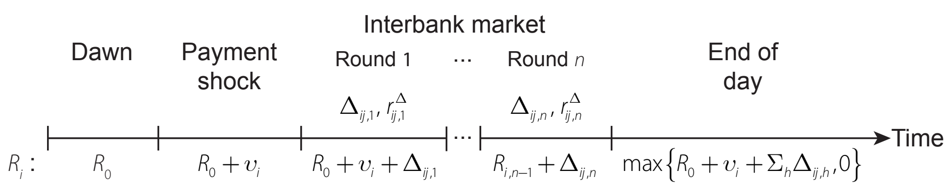
It is easy to see that the Poole model matches the first stylised fact that the overnight rate drops to the floor of the corridor as excess reserves rise. However, it does not match the stylised fact that market volume decreases as well. Aggregate market volume is only a function of the volatility of the early payment shock and hence does not depend on the amount of reserves in the banking system. Moreover, as the interbank market is perfectly competitive, all banks trade at the same rate and thus the model does not generate any dispersion of rates.[11] Finally, the Poole model does not account for counterparty risk.

3.3 Interbank market in Afonso and Lagos (2012)

Afonso and Lagos (2012) present a continuous time model to explain the intraday pattern of reserve holdings in the federal funds market. Among other things, Afonso and Lagos are interested in matching the stylised fact that the distribution of reserve holdings across banks tends to narrow through the day (see Ashcraft and Duffie (2007)). Afonso and Lagos introduce two novelties relative to the Poole model. First, banks trade in an OTC market and, second, banks bargain over terms when they trade. In the model, the OTC market consists of several rounds of random bilateral meetings and the negotiation process is Nash bargaining with equal bargaining power.

The Afonso and Lagos set-up is somewhat intricate; in part, this is to match certain institutional features specific to the federal funds market. Here, we abstract from some of these features and present a bare-bones version which focuses on predictions vis-à-vis the stylised facts presented above. We summarise our simplified version of the Afonso and Lagos (2012) model in the time line in Figure 11.

Figure 11: Time Line – Afonso and Lagos Model



In contrast to the Poole model, the interbank market now consists of n bilateral trading rounds. Banks meet each other at random and they trade as follows. Bank i enters round $h = \{1, \ldots, n\}$ with balances of $R_{i,h-1}$. It is randomly matched with bank j that is holding balances of $R_{j,h-1}$. The bargaining process is such that banks choose the loan size to maximise the joint surplus from trade and they

11 One way to produce time variation in the overnight rate is to introduce uncertainty with regard to the supply of reserves. In our context, let $R_0 = R_{cb} + u$ where R_{cb} is the level of reserves supplied by the central bank, and u is the central bank's forecast error due to autonomous factors.

use the interest rate to split this surplus between them.[12] It turns out – as a result of this trading protocol – that banks equate their reserve holdings when they trade. That is, bank i trades

$$\Delta_{ij,h} = \frac{R_{j,h-1} - R_{i,h-1}}{2} \tag{10}$$

with bank j in round h. A positive value implies that bank i borrows from bank j and a negative value implies that bank i lends to bank j.

In Appendix B, we show that the reserve holdings of bank i at the end of a trading round h is its initial holdings (R_0) plus the average of its own payment shock and those of all the banks that it has traded with, as well as all the banks that they have traded with, and so on up. We let $s \in \mathbf{S}_h$ denote this set of banks that bank i by round h has traded directly or indirectly with. We have:

$$R_{i,h} = R_0 + \frac{1}{2^h} \sum_{s \in \mathbf{S}_h} \upsilon_s. \tag{11}$$

Consequently, banks slowly trade away the payment shock that they received at the start of the day. As payment shocks average to zero, the reserve holdings of banks slowly converge back to R_0 as h increases. The aggregate interbank market volume (Q) is the sum of all trades over all trading rounds, that is, $Q = \Sigma_h \int_i |\Delta_{ij,h}| di$.

Determining the rates at which banks trade in a given round is complicated by the fact that a bank not only considers the value of reserves in terms of meeting its reserve requirement but also the option value of trading them in subsequent rounds. However, the probability of meeting a bank with a specific level of reserves evolves with each trading round as the distribution of reserves shifts according to Equation (9), so the willingness to trade at a specific rate changes as the terminal trading round gets closer. To highlight these dynamics, we turn to an example with two trading rounds.

3.3.1 Example with two rounds

We solve for the equilibrium rates using backward induction. In the last round, bank i and bank j equate their reserve holdings by trading the amount $\left|\Delta_{ij,2}\right| = \frac{1}{2}\left|\left(R_{j,1} - R_{i,1}\right)\right|$. Hence, the end-of-trading balance is $R_{i,2} = R_{j,2} = \frac{1}{2}\left(R_{i,1} + R_{j,1}\right)$. The banks trade at the rates that equate their surplus from trade. The surplus from trade for bank i is

$$S_{i,2} = \left(R_{i,2} - \bar{R}\right)\left[\mathbb{I}_{\{R_{i,2} > \bar{R}\}} r^d + \mathbb{I}_{\{R_{i,2} < \bar{R}\}} r^p\right] - r_2\left(R_{i,1}, R_{j,1}\right)\Delta_{ij,2} - \left(R_{i,1} - \bar{R}\right)\left[\mathbb{I}_{\{R_{i,1} > \bar{R}\}} r^d + \mathbb{I}_{\{R_{i,1} < \bar{R}\}} r^p\right], \tag{12}$$

where $\mathbb{I}_{\{\cdot\}}$ is the indicator function which takes a value of one when the expression {} is true and zero otherwise. The first two terms in Equation (12) are the pay-off from trading and the last term is the pay-off from not trading. The pay-off from trading is the value of bank i's excess reserve holdings (which can be negative) minus the costs or earnings from the overnight loan. Setting $S_{i,2} = S_{j,2}$ and solving for $r_2(R_{i,1}, R_{j,1})$ yields:

12 The interest rate is set so that both banks equate their surplus from trade.

$$r_2\left(R_{i,1},R_{j,1}\right)=\begin{cases} r^d & \text{if} \quad R_{i,1},R_{j,1}\geq\overline{R} \\ \dfrac{R_{i,1}-\overline{R}}{R_{i,1}-R_{j,1}}r^d+\dfrac{\overline{R}-R_{j,1}}{R_{i,1}-R_{j,1}}r^p & \text{if} \quad R_{i,1}>\overline{R}>R_{j,1} \\ \dfrac{R_{j,1}-\overline{R}}{R_{j,1}-R_{i,1}}r^d+\dfrac{\overline{R}-R_{i,1}}{R_{j,1}-R_{i,1}}r^p & \text{if} \quad R_{j,1}>\overline{R}>R_{i,1} \\ r^p & \text{if} \quad R_{i,1},R_{j,1}\leq\overline{R} \end{cases} \tag{13}$$

If both banks fulfil their reserve requirement then they trade at the deposit rate, while if they are both short they trade at the central bank lending facility rate. Otherwise, they trade at a weighted average of the two standing facility rates where the weights reflect the respective reserve holdings relative to the reserve requirement.

Given the rates in the last round, we can now determine the pay-off in the last round for bank *i* if it meets bank *j*:

$$\mathbf{V}_{i,2}\left(R_{i,1},R_{j,1}\right)=r^d\overline{R}+\left(R_{i,2}-\overline{R}\right)\left[\mathbb{I}_{\{R_{i,2}>\overline{R}\}}r^d+\mathbb{I}_{\{R_{i,2}<\overline{R}\}}r^p\right]-r_2\left(R_{i,1},R_{j,1}\right)\Delta_{ij,2}. \tag{14}$$

The first term in Equation (14) is the interest paid on required reserves. The second term is the interest on excess reserves and the last term is the interest on the amount that bank *i* borrows from or lends to bank *j*, as given by Equation (13).

Equipped with the pay-off in the last round, we can find the optimal behaviour of banks in the first round. The surplus from trade if bank *i* meets bank *k* in the first round is

$$S_{i,1}=\int\mathbf{V}_{i,2}\left(\frac{R_{i,0}+R_{k,0}}{2},R_{j,1}\right)dG\left(R_{j,1}\right)-r_1\left(R_{i,0},R_{k,0}\right)\Delta_{ik,1}-\int\mathbf{V}_{i,2}\left(R_{i,0},R_{j,1}\right)dG\left(R_{j,1}\right), \tag{15}$$

where $R_{i,0}=R_0+\upsilon_i$, $R_{k,0}=R_0+\upsilon_k$, $\Delta_{ik,1}=\frac{1}{2}(\upsilon_k-\upsilon_i)$ and $G(R_{j,1})$ is the distribution of reserves across banks at the start of the second round of trading in the interbank market. The first two terms in Equation (15) are the expected pay-off from trading with bank *k*, while the latter is the pay-off from not trading. Equating the surplus of bank *i* and bank *k* ($S_{i,1}=S_{k,1}$) and solving for $r_1(R_{i,0}, R_{k,0})$ yields

$$r_1\left(R_{i,0},R_{0,k}\right)=\int\frac{\mathbf{V}_{i,2}\left(R_{i,0},R_{j,1}\right)-\mathbf{V}_{k,2}\left(R_{k,0},R_{j,1}\right)}{\upsilon_k-\upsilon_i}dG\left(R_{j,1}\right), \tag{16}$$

where we use the facts that: the pay-off in the last round in Equation (16) is the same for banks *i* and *k* because they enter the second round with the same amount of reserves ($R_{i,1}=R_{k,1}$); and $\Delta_{ik,1}=-\Delta_{ki,1}$. Substituting Equations (13) and (15) into Equation (16) and specifying a distribution for the payment shock yields an integral that can be solved – at least using numerical methods. We turn to this next in the following example.

3.3.2 Numerical example

Assume that υ_i follows a normal distribution. From Equation (8) we have that $\Delta_{ij,h}\sim N\left(0,\frac{\sigma_\upsilon}{\sqrt{2^h}}\right)$ and from Equation (9) we have that $R_{i,h}\sim N\left(R_0,\frac{\sigma_\upsilon}{\sqrt{2^h}}\right)$. Hence, by the formula for the half normal distribution, the expected trade size is:

$$E\left[\left|\Delta_{ij,h}\right|\right]=\frac{\sigma_\upsilon}{\sqrt{2^h}}\frac{\sqrt{2}}{\sqrt{\pi}}=\frac{\sigma_\upsilon}{\sqrt{\pi}\sqrt{2^{h-1}}}. \tag{17}$$

The expected volume is

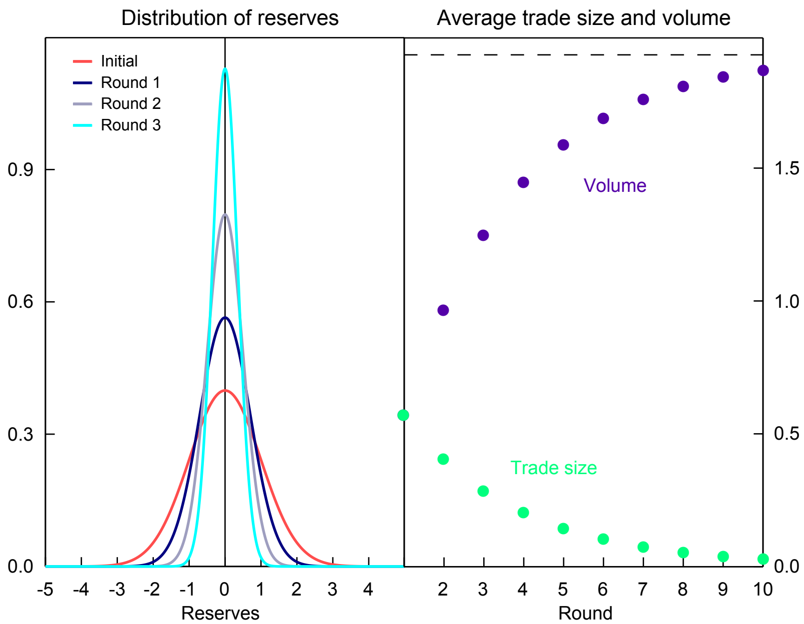
$$E\left[Q_n\left(\sigma_\upsilon\right)\right]=\sum_{h=1}^{n}\int_i E\left[\left|\Delta_{ij,h}\right|\right]di=\frac{\sigma_\upsilon}{\sqrt{\pi}}\sum_{h=1}^{n}\frac{1}{\sqrt{2^{h-1}}}, \tag{18}$$

which increases in the volatility of the payment shock, σ_υ, and in the number of trading rounds, n. But as the average trade size falls in each round, volume converges as n grows large:

$$\lim_{n\to\infty} E\left[Q_n\left(\sigma_\upsilon\right)\right]=\sigma_\upsilon\frac{2}{\sqrt{2\pi\left(\sqrt{2}-1\right)}}=1.926\sigma_\upsilon. \tag{19}$$

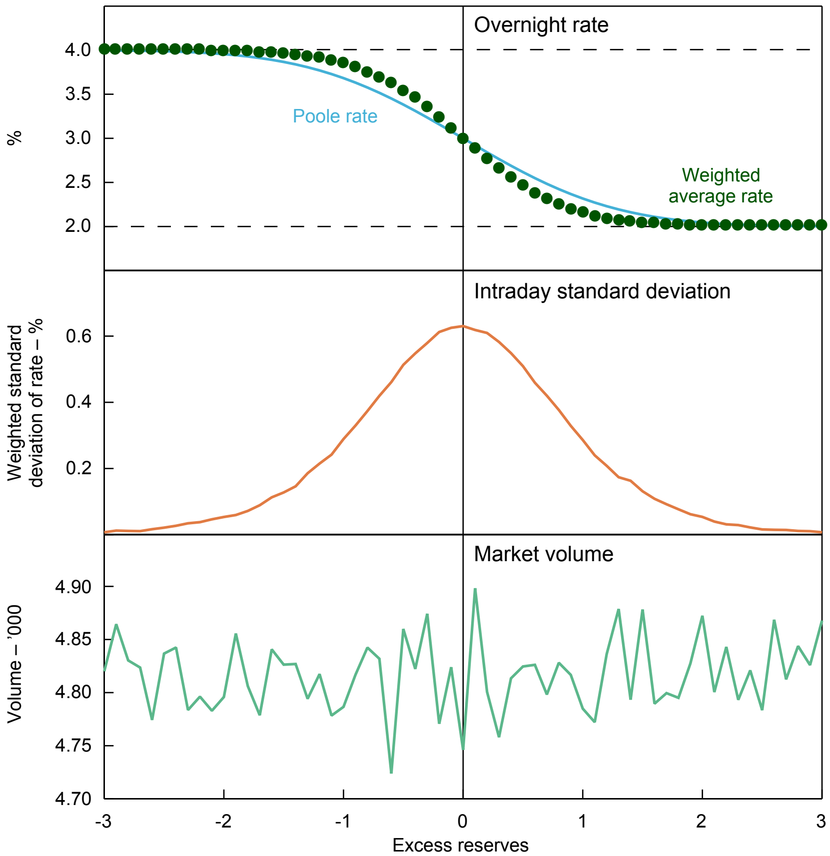
The left-hand panel of Figure 12 plots the initial distribution of reserves as well as distributions for the first three trading rounds assuming that $R_0 = 0$ and standard normal payment shocks. The distribution of reserves narrows as more trading takes place. The right-hand panel of Figure 12 shows the average trade size and the market volume for the first 10 rounds of trading. Unsurprisingly, market volume increases with the number of rounds, but it converges to the limit given in Equation (19).

Figure 12: Afonso and Lagos Model – υ_i ~ *N* (0,1)



Unfortunately, there is no closed form solution for the rates at which banks trade in the first round in Equation (14) – even in this two trading round example. Hence, we simulate the model. As in the Poole example above, we set r^d = 2% and r^p = 4% and we assume that the payment shock is standard normal (see Appendix B). The results for 5 000 trades in each round are shown in Figure 13.

Figure 13: Afonso and Lagos Model – Simulated Overnight Rate, Volatility and Market Volume



The top panel shows the overnight rate as a function of excess reserves. The weighted average rate has a similar shape to the overnight rate in the Poole model. The middle panel shows the dispersion of rates. The (weighted) standard deviation of rates has a bell curve shape centred on zero excess reserves, with volatility dropping to zero when there are large deficits or surpluses of excess reserves. The bottom panel shows the market volume as a function of excess reserves. Here, there is no discernible pattern. In fact, from the formula for the expected trade size in Equation (15), we would expect market volumes to fluctuate around

$$E\left[Q(1)\right]=\frac{5000}{\sqrt{\pi}\sqrt{2^{1-1}}}+\frac{5000}{\sqrt{\pi}\sqrt{2^{2-1}}}=4816, \qquad (20)$$

which is indeed the case.

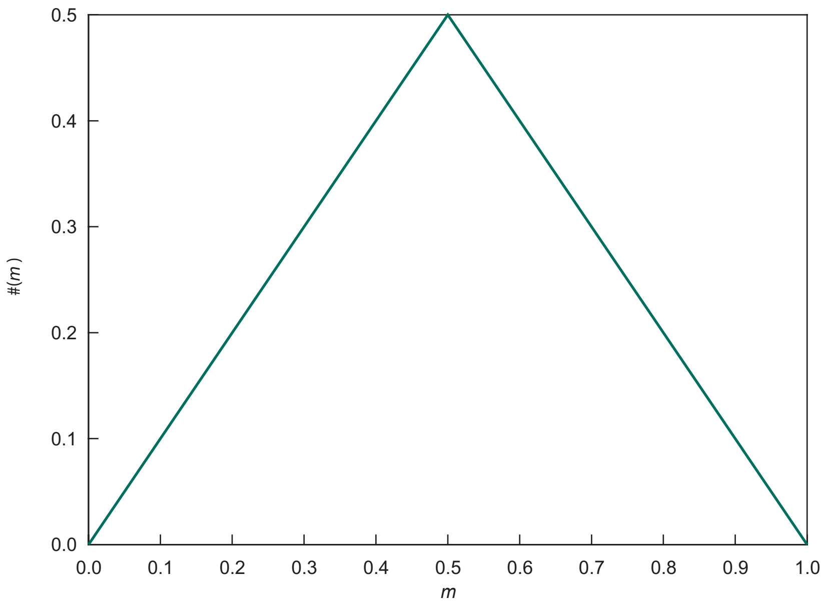
3.3.3 The Afonso and Lagos model and the stylised facts

Like the Poole model, the Afonso and Lagos model fits the first stylised fact because the weighted average rate tends to the deposit rate as the supply of reserves increases. In addition, and in contrast to the Poole model, the Afonso and Lagos framework generates individual trades that occur at different rates. Hence, it is possible to compute the standard deviation of rates. Consistent with the second stylised fact, volatility is predicted to fall when there are a lot of excess reserves in the banking system. However, the Afonso and Lagos model does not match the third stylised fact that market volume decreases as well. As shown above, the aggregate market volume is a function of the volatility of the payment shock and the number of trading rounds but does not depend on the amount of excess reserves. Finally, Afonso and Lagos (2012) does not model default risk.

3.4 Interbank market in Bech and Monnet (2013)

In Bech and Monnet (2013), the interbank market is modelled as a three-step process. In the first step, banks decide whether they wish to borrow or lend based on their stock of reserves. Let m denote the measure of borrowers and hence $1 - m$ is the measure of lenders. Once this 'either a borrower or lender be' decision is made, banks turn to a broker in the second step. The broker seeks to match the bank with another that wants to be on the other side of the trade. However, some banks will not be matched if there are more borrowers than lenders or vice versa.[13] The number (or measure) of matches is $\#(m) = \min\{m, 1 - m\}$ as shown in Figure 14.

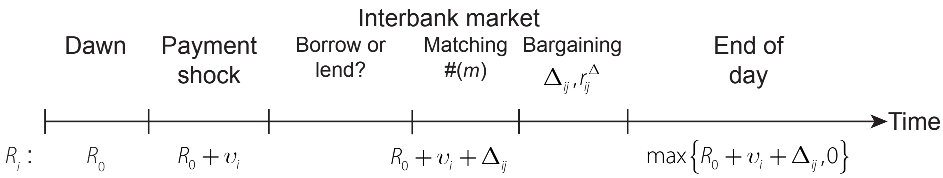
Figure 14: Number of Matches



13 The broker is not able to match banks according to their relative reserve positions.

If a borrower is matched with a lender, the two banks, in step three, bargain over the amount of reserves to be traded Δ_{ij} and the price r_{ij}^{Δ}. Like Afonso and Lagos (2012), Nash bargaining describes the outcome of the interbank negotiations and banks have equal bargaining power. The time line below (Figure 15) summarises the steps of the Bech and Monnet (2013) model.

Figure 15: Time Line – Bech and Monnet Model



The key to determining the equilibrium is the decision of each bank to become either a borrower or a lender. Bech and Monnet (2013) show that a bank chooses to become a lender in the interbank market if it has more reserves than required $\left(R_i > \bar{R}\right)$ and chooses to become a borrower if it has less than required $\left(R_i < \bar{R}\right)$. In equilibrium, banks equate their reserve holdings when they trade

$$\Delta_{ij}\left(R_i, R_j\right) = \Delta\left(R_b, R_l\right) = \frac{R_l - R_b}{2}, \tag{21}$$

where, without loss of generality, we assume that $R_i < R_j$ so that bank i is always the borrower (b) and bank j is always the lender (l). In Appendix C, we show that the equilibrium rate on the loan is given by:

$$r^{\Delta}\left(R_b, R_l, \bar{R}\right) = r^d \frac{R_l - \bar{R}}{R_l - R_b} + r^p \frac{\bar{R} - R_b}{R_l - R_b} \qquad \text{where} \qquad R_b < \bar{R} < R_l. \tag{22}$$

3.4.1 Counterparty risk

Bech and Monnet (2013) also introduce the possibility of default into the decision process of banks to capture the fact that counterparty risk can play an important role even for overnight lending, as highlighted by the financial crisis. Assume that a bank default has an exogenous given probability of $\delta \in [0, 1)$. If a borrower defaults, the lender gets nothing, but if a lender defaults the borrower still has to pay in full the other creditors of the lender. It turns out that the decision of a bank to become a borrower or a lender is unchanged and the rates at which banks trade in equilibrium are given by

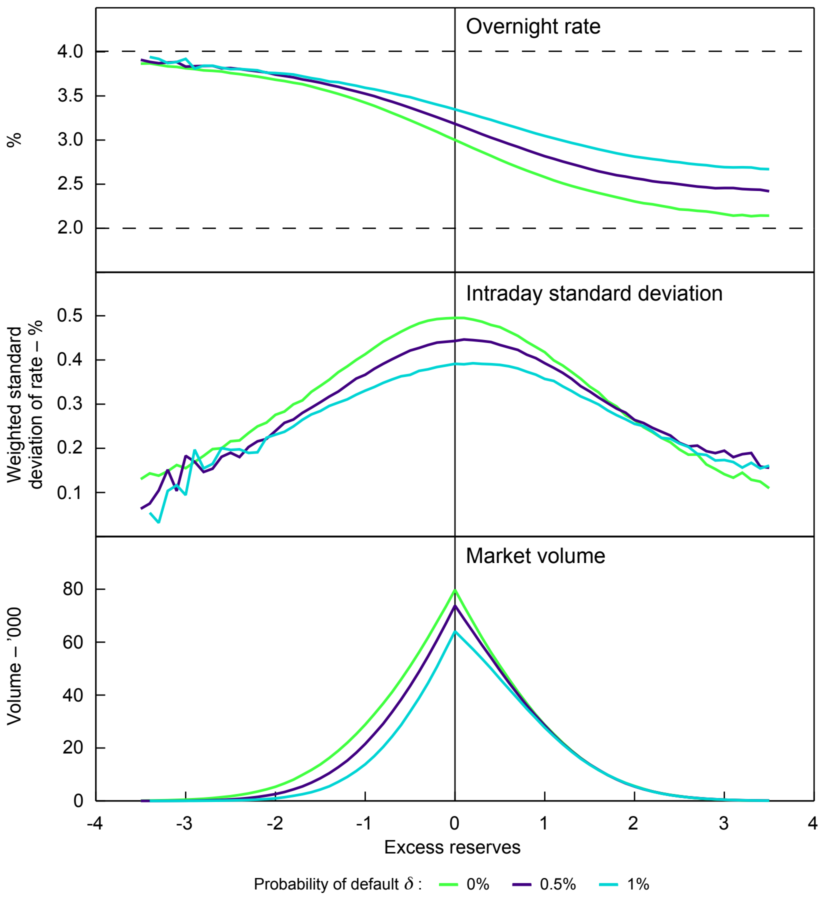
$$r^{\Delta}\left(R_b, R_l, \bar{R}, \delta\right) = r^{\Delta}\left(R_b, R_l, \bar{R}\right) + \frac{\delta}{2-\delta}\left[1 + r^{\Delta}\left(R_b, R_l, \bar{R}\right)\right], \tag{23}$$

where $R_b < \bar{R} < R_l$ and $r^{\Delta}\left(R_b, R_l, \bar{R}\right)$ is the loan rate without credit risk in Equation (19). In words, the possibility of default introduces a risk premium that reflects the potential principal loss and is proportional to the overnight rate without credit risk. Importantly, when the probability of default is sufficiently high, it is possible that the rate at which a lender is willing to lend is larger than the rate the central bank charges for its lending facility. In such circumstances banks will not trade and borrowers will turn to the central bank instead. In fact, it is possible that the interbank market disappears. Assuming that there is trade we can – as before – simulate the model.

3.4.2 Numerical example

Again, we set r^d = 2% and r^p = 4% and assume that the payment shock is standard normal. Figure 16 shows the overnight rate, the standard deviation of rates and the market volume as a function of the amount of excess reserves for three different levels of the probability of default, $\delta \in \{0\%, 0.5\%, 1\%\}$. The figure is based on 200 000 draws for each level of excess reserves (see Appendix C for further details).

Figure 16: Overnight Rate, Volatility and Market Volume with Credit Risk



We begin with the case of no counterparty risk (the green line). The weighted average rate has a similar shape to the overnight rate in the Poole and Afonso and Lagos models. The middle panel shows the dispersion of rates. The weighted standard deviation of rates has a bell curve shape centred on zero excess reserves with volatility dropping towards zero in case of large deficits or surpluses of excess reserves. The bottom panel shows market volume as a function of excess reserves. Volume peaks when there are zero excess reserves in the system and it drops to zero when liquidity conditions become unbalanced in either direction.

Increasing counterparty risk (purple and blue lines) increases the average overnight rate for a given level of excess reserves. In other words, the effective width of the corridor narrows when uncertainty with respect to the reliability of counterparties rises. In contrast, volatility and market volume decrease with higher default risk unless excess reserves are plentiful.

3.4.3 The Bech and Monnet model and the stylised facts

Like the two other models, the Bech and Monnet model fits the first stylised fact well. Moreover, as with the Afonso and Lagos framework, it generates individual trades that occur at different rates and is consistent with the second stylised fact that volatility falls when there are a lot of excess reserves. Furthermore, the model also fits with the third stylised fact that market volume decreases as excess reserves increase. In addition, it models counterparty risk, showing that higher default risk pushes up the overnight rate. This is in line with the experience in Australia, as well as the comparison between the Eonia and EURONIA markets. Unlike the Afonso and Lagos model, however, it does not provide any predictions with respect to the intraday pattern of trading or reserve holdings. This requires multiple rounds of trading.

4. Conclusion

In this paper, we establish what we think are four stylised facts around the price and quantity dynamics of the overnight interbank market during a period of unconventional monetary policies. The stylised facts are that a substantial increase in the amount of excess reserves in the banking system: (1) drives the overnight rate to the floor of the corridor; (2) reduces the volatility of the overnight rate; and (3) decreases market volume. A fourth stylised fact is that counterparty risk pushes up the overnight rate. In light of these stylised facts, we review three models of the interbank market and monetary policy implementation and test whether the predictions of these models are consistent with the facts. The models are: the standard model of monetary policy implementation in a corridor system, based on the seminal contribution of Poole (1968); the recent application of search theory to the interbank market of Afonso and Lagos (2012); and the directed search model with counterparty risk in Bech and Monnet (2013). Table 1 summarises the results for these three models.

Table 1: Stylised Facts and Model Predictions

	Poole (1968)	Afonso and Lagos (2012)	Bech and Monnet (2013)
A surge in excess reserves:			
(1) drives the o/n rate to the floor of corridor	✓	✓	✓
(2) reduces the volatility of overnight rate	na	✓	✓
(3) decreases market volume	na	na	✓
Counterparty risk pushes up the o/n rate	na	na	✓

In sum, the models can explain either a subset or all of the stylised facts. In other words, the observed dynamics in the overnight money market are in line with what we would expect as a consequence of the observed market stresses and unconventional policies. Taken at face value this suggests that while it is true that activity in the interbank market in certain jurisdictions has almost ceased (see, for example, Jeffrey (2012)) it may re-emerge once the unconventional policies and market stresses are reversed. If so, central banks will be able to resume their usual *modus operandi*. Unsurprisingly, a number of caveats apply to this assertion. First, as noted in BIS (2010, pp 42–43), prolonged periods of low policy rates and market volumes can erode key market structures and relationships that are not easily rebuilt. For example, the tightening of Japan's monetary policy in 2006 was complicated by the fact that the money market desks had been significantly reduced at commercial banks. Second, the assessment of counterparty risk within the banking system might have changed fundamentally, which could lead to turnover being permanently lower. Third, the new liquidity regulations that are part of Basel III might change the underlying economics of overnight loan transactions (see, for example, Bonner and Eijffinger (2012) and Bech and Keister (2013)).

Appendix A: Definition and Computation of Overnight Rates

This appendix provides details on the definition and computation of the overnight money market rates discussed in the main text. Unless otherwise noted, the information was collected from central bank and industry association websites.

Federal (fed) funds rate

A federal (fed) funds transaction is an unsecured loan of US dollars to a depository institution from a lender (or seller) that is a depository institution, foreign bank, government-sponsored enterprise or other eligible entity. Fed funds transactions are excluded from reservable liabilities. Participants can arrange fed funds transactions directly with each other (bilaterally), or through the brokers. Because there is no central repository of fed funds transactions, there is no central collection of the rates at which they occurred. However, for decades fed funds brokers have voluntarily submitted aggregated data on the fed funds transactions they have brokered to the Federal Reserve Bank of New York (FRBNY). The FRBNY uses these data to calculate the effective federal funds rate and related summary statistics. Various academic studies and discussions with market participants provide confidence that the effective federal funds rate is broadly representative of the entire universe of fed funds trades.

Eonia®

Eonia® (Euro Overnight Index Average) is the effective overnight reference rate for the euro. It is computed as a weighted average of all overnight unsecured lending transactions in the interbank market, undertaken in the European Union and European Free Trade Association countries. Eonia® is computed with the help of the European Central Bank. The banks contributing to Eonia® are the same banks as the Panel Banks quoting for Euribor®.

EURONIA

Introduced in January 1999, EURONIA is the Euro Overnight Index Average. This index tracks actual market overnight funding rates. EURONIA is the weighted average rate to four decimal places of all unsecured euro overnight cash transactions brokered in London by contributing Wholesale Markets Brokers' Association members between midnight and 16:00 with all counterparties and no minimum deal size. The index is the weighted average overnight deposit rate for each business day. Each rate in the average is weighted by the principal amount of deposits that were taken on that day.

SONIA

Introduced in March 1997, SONIA is the Sterling Overnight Index Average. The index tracks actual market overnight funding rates. SONIA is the weighted average rate to four decimal places of all unsecured sterling overnight cash transactions brokered in London by contributing Wholesale Markets Brokers' Association members between midnight and 16:15 with all counterparties and a minimum deal size of £25 million. The SONIA is published by 17:00 on the day of calculation. The index is a weighted average overnight deposit rate for each business day. Each rate in the average is weighted by the principal amount of deposits that were taken on that day.

Call rate (Japan)

The uncollateralised call rate is the interest rate for uncollateralised transactions in the call market, where financial institutions lend and borrow short-term funds. The rate at which funds are received and paid on a contract day, and at which reverse transactions are conducted on the business day following the contract day, are included in the uncollateralised overnight call rate.

Overnight money market financing rate (Canada)

The overnight money market financing rate is an estimate compiled at the end of the day by the Bank of Canada through a survey of major participants in the overnight market (Reid 2007). This estimate comprises the weighted average repo funding cost of major money market dealers, including special purchase and resale agreements (SPRAs)[14] with the Bank of Canada and trades that are conducted directly between dealers. It provides a somewhat broader measure than the Canadian Overnight Repo Rate Average (CORRA).[15]

Cash rate (Australia)

The Reserve Bank of Australia collects data on the amount and weighted average rate at which banks transact in the domestic interbank market for overnight unsecured funds. These data are used to calculate the Bank's measure of the Interbank Overnight Cash Rate (IBOC), which is the Reserve Bank Board's operational target for monetary policy. This measure is published each day that the Reserve Bank Information and Transfer System (RITS) is open for interbank settlement. All banks that settle payments across their own Exchange Settlement account participate in the survey (around 50 in number).

14 SPRAs and SRAs are repo-type and reverse repo-type transactions, respectively, in which the Bank of Canada offers to purchase (sell) Government of Canada securities from designated counterparties with an agreement to sell (buy) them back at a predetermined price on the next business day.

15 The CORRA consists of a weighted average of rates on repo transactions conducted onscreen between 06:00 and 16:00 that are subsequently reported by interdealer brokers. The CORRA is limited to repo transactions that involve general collateral (GC).

Appendix B: The Afonso and Lagos (2012) Model

In this appendix, we derive the equations describing the evolution of reserve balances in Afonso and Lagos (2012) and provide details on our simulation exercise.

Evolution of reserve balances

From Section 3, we have that the reserve holdings of bank i at the beginning on the interbank market are:

$$R_{i,0} = R_0 + \upsilon_i.$$

From Equation (8) we have that at the end of the first round, bank i's reserve holdings are:

$$R_{i,1} = R_{i,0} + \frac{R_{j,0} - R_{i,0}}{2} = R_0 + \upsilon_i + \frac{\upsilon_j - \upsilon_i}{2} = R_0 + \frac{\upsilon_j + \upsilon_i}{2}.$$

At the end of the second round they are:

$$R_{i,2} = R_{i,1} + \frac{R_{k,1} - R_{i,1}}{2} = R_0 + \frac{\upsilon_j + \upsilon_i}{2} + \frac{\frac{\upsilon_k + \upsilon_l}{2} - \frac{\upsilon_j + \upsilon_i}{2}}{2} = R_0 + \frac{\upsilon_k + \upsilon_l + \upsilon_j + \upsilon_i}{4}.$$

At the end of the third round they are:

$$R_{i,3} = R_{i,2} + \frac{R_{m,2} - R_{i,2}}{2} = R_0 + \frac{\upsilon_k + \upsilon_l + \upsilon_j + \upsilon_i}{4} + \frac{\frac{\upsilon_m + \upsilon_n + \upsilon_o + \upsilon_p}{4} - \frac{\upsilon_k + \upsilon_l + \upsilon_j + \upsilon_i}{4}}{2}$$
$$= R_0 + \frac{\upsilon_m + \upsilon_n + \upsilon_o + \upsilon_p + \upsilon_k + \upsilon_l + \upsilon_j + \upsilon_i}{8}.$$

Hence, by induction we have Equation (11).

Simulation

In the simulation of the two round example of the Afonso and Lagos (2012) model, we set $r^d = 2\%$ and $r^p = 4\%$ and we assume that the payment shock is standard normal. We vary the initial level of reserves from –3 to 3 in steps of 0.1. In the first round, we draw 10 000 payment shocks and randomly match banks into 5 000 trades. For each triple of R_0, υ_i and υ_k, we compute $\Delta_{ik,1}$ and $r_1(R_{i,0},R_{k,0})$. The latter is determined by computing the integral in Equation (16) using the fact that $R_{j,1} \sim N\left(R_0, \left(\sqrt{2^h}\right)^{-1}\right)$. For the second round we draw 10 000 shocks from $N\left(0, \left(\sqrt{2^h}\right)^{-1}\right)$ to mirror the average of two payment shocks. We compute $\Delta_{ij,2}$ and $r_2(R_{i,1},R_{j,1})$. The latter comes directly from Equation (13). For each initial level of reserves $R_0 \in \{-3, -2.9, \ldots, 2.9, 3\}$, we then compute the market volume, weighted average overnight rate and weighted standard deviation based on the 10 000 trades conducted over the two rounds.

Appendix C: The Bech and Monnet (2013) Model

In this appendix, we derive the equilibrium overnight interest rate in the case of no credit risk.

Equilibrium rate

There are two potential cases: first that $R_b + R_l \geq 2\bar{R}$, and second that $R_b + R_l < 2\bar{R}$. In the first case we have by Equation (21) that $R_b + \Delta = R_l + \Delta > \bar{R}$ and hence the surplus of the borrower from trading (compared with no trade) is:

$$S_b^{\text{I}} = \underbrace{r^d\left(R_b - \Delta - \bar{R}\right) + r^d\bar{R} - r^{\Delta}\Delta}_{\text{trade profit}} - \underbrace{\left[r^p\left(R_b - \bar{R}\right) + r^d\bar{R}\right]}_{\text{no trade profit}} = \left(r^d - r^p\right)\left(R_b - \bar{R}\right) + \left(r^d - r^{\Delta}\right)\Delta.$$

Similarly the surplus of the lender is:

$$S_l^{\text{I}} = \underbrace{r^d\left(R_l - \Delta - \bar{R}\right) + r^d\bar{R} + r^{\Delta}\Delta}_{\text{trade profit}} - \underbrace{\left[r^d\left(R_l - \bar{R}\right) + r^d\bar{R}\right]}_{\text{no trade profit}} = \left(r^{\Delta} - r^d\right)\Delta.$$

Equating S_b^{I} and S_l^{I} yields $\left(r^d - r^p\right)\left(R_b - \bar{R}\right) + \left(r^d - r^{\Delta}\right)\Delta = \left(r^{\Delta} - r^d\right)\Delta$, which implies that:

$$r^{\Delta} = r^d - \left(r^d - r^p\right)\frac{\bar{R} - R_b}{R_l - R_b} = r^d\,\frac{R_l - \bar{R}}{R_l - R_b} + r^p\,\frac{\bar{R} - R_b}{R_l - R_b}.$$

In the latter case, the borrower surplus is:

$$S_b^{\text{II}} = r^p\left(R_b + \Delta - \bar{R}\right) + r^d\bar{R} - r^{\Delta}\Delta - \left[r^p\left(R_b - \bar{R}\right) + r^d\bar{R}\right] = \left(r^p - r^{\Delta}\right)\Delta.$$

The lender surplus is:

$$S_l^{\text{II}} = r^p\left(R_l - \Delta - \bar{R}\right) + r^d\bar{R} + r^{\Delta}\Delta - \left[r^d\left(R_l - \bar{R}\right) + r^d\bar{R}\right] = \left(r^p - r^d\right)\left(R_l - \bar{R}\right) + \left(r^{\Delta} - r^p\right)\Delta.$$

Equating S_b^{II} and S_l^{II} yields $\left(r^p - r^{\Delta}\right)\Delta = \left(r^p - r^d\right)\left(R_l - \bar{R}\right) + \left(r^{\Delta} - r^p\right)\Delta$ which implies that

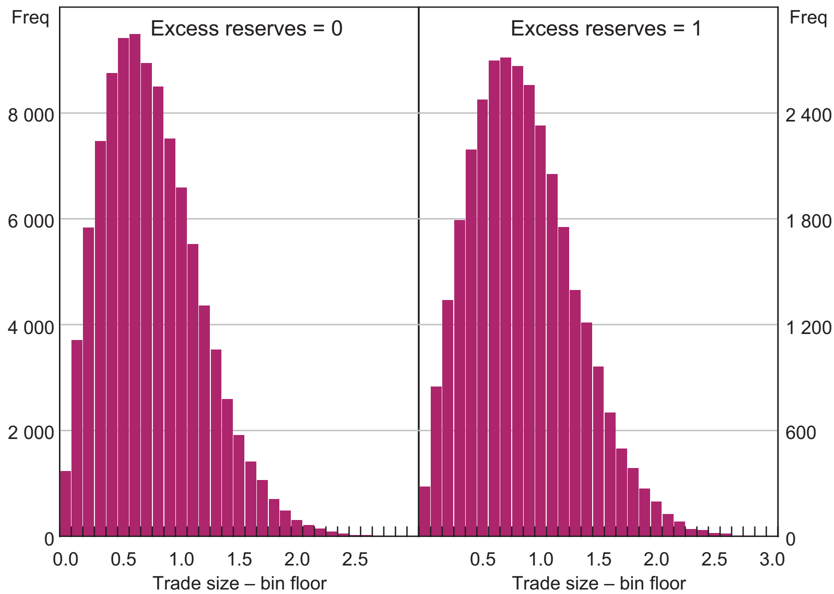
$$r^{\Delta} = r^p + \left(r^p - r^d\right)\frac{\bar{R} - R_l}{R_l - R_b} = r^d\,\frac{R_l - \bar{R}}{R_l - R_b} + r^p\,\frac{\bar{R} - R_b}{R_l - R_b},$$

the same as in the first case.

Simulation

Figure C1 shows histograms of trade sizes from two simulation runs of our model without credit risk. In the left-hand panel, the amount of excess reserves is zero whereas excess reserves are positive in the right-hand panel.

Figure C1: Trade Size Distributions – $\upsilon_i \sim N(0,1)$



Number of trades:	99 905	Number of trades:	31 665
Mean:	0.8	Mean:	0.9
Total volume:	79 872	Total volume:	28 521

With zero excess reserves, half of the banks are borrowers and the other half are lenders on average. Consequently, the broker is expected to match 100 000 trades. In the actual simulations, the number of matches was 99 905, as reported in the tables below the individual histogram in Figure C1. In contrast, with positive excess reserves, there are more lenders than borrowers and the broker obviously finds fewer matches. With excess reserves of one, there are

$$\frac{\Pr(lender)}{\Pr(borrower)} = \frac{1}{\Phi(-1)} - 1 = \frac{84.1\%}{15.9\%} = 5.3$$

lenders for every borrower and the expected number of matches is 31 731. The actual number in the simulation reported here was 31 665.

References

Afonso G and R Lagos (2012), 'Trade Dynamics in the Market for Federal Funds', Federal Reserve Bank of New York Staff Report No 549.

Angelini P, A Nobili and C Picillo (2011), 'The Interbank Market after August 2007: What Has Changed, and Why?', *Journal of Money, Credit and Banking*, 43(5), pp 923–958.

Ashcraft AB and D Duffie (2007), 'Systemic Illiquidity in the Federal Funds Market', *The American Economic Review*, 97(2), pp 221–225.

Bech ML and T Keister (2013), 'Liquidity Regulation and the Implementation of Monetary Policy', BIS Working Papers No 432.

Bech ML and E Klee (2011), 'The Mechanics of a Graceful Exit: Interest on Reserves and Segmentation in the Federal Funds Market', *Journal of Monetary Economics*, 58(5), pp 415–431.

Bech ML and C Monnet (2013), 'Interbank Money Market and Unconventional Monetary Policy', unpublished manuscript, Bank for International Settlements.

Berentsen A and C Monnet (2008), 'Monetary Policy in a Channel System', *Journal of Monetary Economics*, 55(6), pp 1067–1080.

Bindseil U (2004), *Monetary Policy Implementation: Theory, Past, and Present*, Oxford University Press, Oxford.

BIS (Bank for International Settlements) (2010), *80th Annual Report*, Bank for International Settlements, Basel.

Bonner C and CW Eijffinger (2012), 'The Impact of the LCR on Interbank Money Markets', Centre for Economic Policy Research Discussion Papers Series No 9124.

Borio C and P Disyatat (2010), 'Unconventional Monetary Policies: An Appraisal', *The Manchester School*, 78(s1), pp 53–89.

Christensen HE, JA Lopez and GD Rudebusch (2009), 'Do Central Bank Liquidity Facilities Affect Interbank Lending Rates?', Federal Reserve Bank of San Francisco Working Paper No 2009-13.

Clinton K (1997), 'Implementation of Monetary Policy in a Regime with Zero Reserve Requirements', Bank of Canada Working Paper 97-8.

Cœuré B (2013a), 'Ensuring the Smooth Functioning of Money Markets', Keynote speech at Clearstream's 17th Global Securities Financing Summit, Luxembourg, 16–17 January.

Cœuré B (2013b), 'Where to Exit To? Monetary Policy Implementation After the Crisis', Speech at International Center for Monetary and Banking Studies ICMB/CEPR 15th Geneva Conference on the World Economy 'Exit Strategies: Time to Think About Them', Geneva, 3 May.

Debelle G (2008), 'Market Operations in the Past Year', Speech at the 2008 Finance & Treasury Association Congress, Melbourne, 31 October.

Ennis HM and T Keister (2008), 'Understanding Monetary Policy Implementation', Federal Reserve Bank of Richmond *Economic Quarterly*, 94(3), pp 235–263.

FOMC (Federal Open Markets Committee) (2013), 'Minutes of the Federal Open Market Committee, April 30–May 1, 2013', Board of Governors of the Federal Reserve System, Washington DC. Available at <http://www.federalreserve.gov/monetarypolicy/fomcminutes20130501.htm>.

Heider F, M Hoerova and C Holthausen (2009), 'Liquidity Hoarding and Interbank Market Spreads: The Role of Counterparty Risk', ECB Working Paper No 1126.

Jeffery C (2012), 'Interbank Market "Almost Dead" in Europe, Says Banque de France's Mongars', Central Banking.com, 29 March. Available at <www.centralbanking.com/central-banking/news/2164700/interbank-market-almost-dead-europe-banque-france-s-mongars>.

Kreicher L, R McCauley and P McGuire (2013), 'The 2011 FDIC Assessment on Banks' Managed Liabilities: Interest Rate and Balance-Sheet Responses', BIS Working Papers No 413.

McAndrews J, A Sakar and Z Wang (2008), 'The Effect of the Term Auction Facility on the London Inter-Bank Offered Rate', Federal Reserve Bank of New York Staff Report No 335.

Maraffino G and L Fransolet (2012), 'ECB: To Exit or Not?', *Barclays Euro Money Market Weekly*, 2 April, pp 1–4.

Michaud F-L and C Upper (2008), 'What Drives Interbank Rates? Evidence from the Libor Panel', *BIS Quarterly Review*, March, pp 47–58.

Poole W (1968), 'Commercial Bank Reserve Management in a Stochastic Model: Implications for Monetary Policy', *The Journal of Finance*, 23(5), pp 769–791.

Reid C (2007), 'The Canadian Overnight Market: Recent Evolution and Structural Changes', *Bank of Canada Review*, Spring, pp 15–29.

Schwarz K (2010), 'Mind the Gap: Disentangling Credit and Liquidity in Risk Spreads'. Available at <SSRN:http://ssrn.com/abstract=1486240>.

Stark J (2011), 'Welcome Address', Address at the ECB Workshop 'The Post-Crisis Design of the Operational Framework for the Implementation of Monetary Policy', Frankfurt, 10–11 October. Available at <http://www.ecb.europa.eu/events/conferences/shared/pdf/pocrides_opfram/stark.pdf?98ccdfd9632e09d524d9d9d9969b30ea>.

Stone M, K Fujita and K Ishi (2011), 'Should Unconventional Balance Sheet Policies be Added to the Central Bank Toolkit? A Review of the Experience So Far', IMF Working Paper No WP11/145.

Taylor JB and JC Williams (2008), 'Further Results on a Black Swan in the Money Market', SIEPR Discussion Paper 07-046.

Taylor JB and JC Williams (2009), 'A Black Swan in the Money Market', *American Economic Journal: Macroeconomics*, 1(1), pp 58–83.

Whitesell W (2006), 'Interest Rate Corridors and Reserves', *Journal of Monetary Economics*, 53(6), pp 1177–1195.

Woodford M (2001), 'Monetary Policy in the Information Economy', Paper presented at the Federal Reserve Bank of Kansas City Economic Symposium 'Economic Policy for the Information Economy', Jackson Hole, 30 August–1 September.

Zhang N (2012), 'Estimating the Demand for Settlement Balances in the Canadian Large Value Transfer System', Bank of Canada Working Paper 2012-15.

Discussion

1. Ippei Fujiwara

The paper by Morten Bech and Cyril Monnet considers the interbank market during and after the global financial crisis (GFC), characterising it by four stylised facts:

1. The higher the level of excess reserves, the lower the overnight interest rate.
2. The higher the level of excess reserves, the lower the dispersion of overnight interest rates.
3. The higher the level of excess reserves, the lower the volume of trade in the overnight interbank market.
4. Larger counterparty risks increase the overnight interest rate.

The authors present a single model which can simultaneously explain many of these observed features. This is central to its valuable contribution.

Contribution to the literature

Often these four facts are considered to be obvious but, on reflection, some explanation is necessary. For someone unfamiliar with the reserve system, the fact that the central bank can control the overnight interest rate in a linked interbank market is not a trivial matter. Also, simple supply and demand conditions do not say anything about heterogeneity – for example, in interest rate volatility or trade volumes – so a separate model is needed to explain these facts.

The authors' significant achievement is to construct a framework to examine how well various models can explain these facts. By presenting the model in the context of the previous literature, the authors helpfully illustrate the development of thinking in this field. Accordingly, the framework will serve as a useful tool for understanding the interbank market, and aid thinking about the effectiveness of unconventional monetary policy in the future.

Model mechanisms and intuition

Poole

The intuition that underlies the various models can be seen by assuming, for simplicity of analysis, but without loss of generality, that the target level of reserves for commercial banks is zero. Poole (1968) considers before-trade and after-trade shocks. Monetary policy controls banks' initial reserve positions and after-trade shocks prevent banks from fully matching their reserve demand through interbank trade in the overnight market. Another feature is the corridor system, which comprises two official interest rates: the deposit rate, r^D, and the lending rate, r^W, with $r^W > r^D$. If, following an after-trade shock, a bank has a negative reserve position, it pays r^W. Conversely, if it has a positive reserve position, it is remunerated at the lower deposit rate, r^D. The key equation in the model involves equating, by (statistical) arbitrage, the interbank interest rate, r^Δ, to the expected *ex post* interest rate that the commercial bank faces in the corridor system. That is:

$$r^{\Delta} = r^{W} * \Pr(negative) + r^{D} * \Pr(positive). \quad (1)$$

If all banks expect to be in the positive region following the after-trade shock, the interest rate in the overnight market must be r^D. If, on the other hand, banks expect the converse to hold, the interbank rate must be r^W, the lending rate. Depending on the reserve position, the interbank rate should move between these levels. This market clearing mechanism captures the relationship between quantity and price. Increasing the initial holding of reserves via unconventional monetary policy will naturally increase the volume of excess reserves and reduce the probability that banks settle in the negative region. This yields the first result: the higher the excess reserves, the lower the overnight interest rate.

However, the competitive market clearing condition yields a single overnight rate, which implies that the model is silent about the volatility of overnight rates. Furthermore, trade volumes are pinned down only by the dispersion of the before-trade shock, and therefore the model can say nothing about unconventional monetary policy. Nor does the model address counterparty risk.

Afonso and Lagos

In Afonso and Lagos (2012), banks trade bilaterally after shocks hit the economy. There is no need for after-trade shocks, since decentralised trade results in position heterogeneity. Interbank trade involves matching the reserve positions of banks. In the absence of an aggregate market clearing condition, Nash bargaining produces heterogeneous interest rates through the random matching of banks that have different positions after shocks. In each trade, banks determine the rate they are prepared to pay by considering their post-trade reserve position, and in particular whether they will be above target.

In this model, if the initial reserve position is very large (small), then all the banks end up with positive (negative) reserve positions, and thus all traded interest rates are the deposit rate r^D (the lending rate r^W), with no dispersion. Thus the model can explain the second stylised fact: the higher the level of excess reserves, the lower the dispersion of overnight interest rates.

However, with regard to the third stylised fact, shocks will create heterogeneous reserve positions and thus trade occurs irrespective of the initial positions as determined by unconventional monetary policy. The model identifies no clear relationship between excess reserves and trade volumes. Counterparty risk is again not covered in this model.

Bech and Monnet

The trick in Bech and Monnet (2013) is that trade happens only between banks with positive and those with negative positions. In Afonso and Lagos (2012), irrespective of how high a reserve position a bank has, any meeting between banks with differing positions will lead to trade. Here, by comparison, if the banks already both have positions above the target level, there is no need to undertake trade, since both are already meeting the target. This delivers the conclusion that as the volume of excess reserves increases, trade volumes fall. This simple additional restriction on trade allows the model to explain the first three stylised facts.

Default risk is also incorporated into the model. As default risk increases the cost of lending, the interest rate banks lend at accordingly rises. The paper refers to this as a risk premium, although technically it appears to be a credit spread to offset downside risk.

Comments

The model in Bech and Monnet (2013) nicely explains the stylised facts, and could be a benchmark model for positive analysis to understand the interbank market theoretically. From this positivist perspective, I have no substantive comments to make. However, several comments can be made about the normative implications of the model and the implementation of unconventional monetary policy.

The model considers how unconventional monetary policy affects interbank interest rates, dispersion of interest rates, and trade volumes in the overnight interbank market. Normative implications are outside the scope of the paper, since there is no modelled distortion in the interbank market. The stance of the paper appears to be that distortions exist outside the interbank market, and a new form of monetary policy is needed to tackle these distortions. However, it is not clear that there are no distortions in the interbank market.

Rather, unconventional monetary policy seems to be, at least in part, intended to address the functioning of the interbank market, in addition to macroeconomic considerations. It is questionable whether the sharp rise in the LIBOR-OIS spread was an optimal outcome for banks. Having said this, it is difficult to identify excessive risk aversion by banks, and it is unclear whether public policy should be used to reduce excessive risk premia in financial markets if they simply reflect agents' preferences. Normatively speaking, if such distortions could be evaluated, there is a case to consider costs versus benefits. The costs of unconventional monetary policy tend to be ignored, but there must be substantial costs in terms of legal costs or overtime of central bank employees. It would be desirable to know how large these are compared with the gains from eliminating distortions.

Finally, in the model, unconventional monetary policy is simply the control of original reserve positions, which presents no difficulty here. However, there are many variations of unconventional monetary policies to increase excess reserves.[1] Central banks also seem to care about which assets to purchase, an aspect missing from the paper. Also, increasing excess reserves becomes less trivial when considering stigma, which will tend to prevent central banks from extending excess reserves to those that need them most. This stigma issue is a potentially interesting mechanism design question in the future.

References

Afonso G and R Lagos (2012), 'Trade Dynamics in the Market for Federal Funds', Federal Reserve Bank of New York Staff Report No 549.

Bech ML and C Monnet (2013), 'Directed Search in the Interbank Money Market', Paper presented at the European Central Bank Workshop on 'Structural Changes in Money Markets: Implications for Monetary Policy Implementation', Frankfurt, 30 September–I October.

Poole W (1968), 'Commercial Bank Reserve Management in a Stochastic Model: Implications for Monetary Policy', *The Journal of Finance*, 23(5), pp 769–791.

1 For example, at the Federal Reserve, these include the Term Auction Facility (TAF), Primary Dealer Credit Facility (PDCF), Term Securities Lending Facility (TSLF), Asset-backed Commercial Paper Money Market Mutual Fund Liquidity Facility (AMLF), Commercial Paper Funding Facility (CPFF), Money Market Investor Funding Facility (MMIFF) and Term Asset-backed Securities Loan Facility (TALF).

2. General Discussion

Much of the discussion of this paper followed from a comment that both the model and experience demonstrated that excess liquidity provision by central banks could crowd out private bank activity in the overnight market. Although control of the interest rate would be retained in a corridor system in these circumstances, several participants noted that excess reserves could increase to the point that there was no trade in the interbank market. One consequence of this was a decline in the monitoring of counterparties, which was an inherent feature of trade in the overnight market.

One participant inquired as to what this might mean for the optimal monetary policy framework. New Zealand was cited as an example of a country that had adjusted its operations with regard to paying interest on reserves because this loss of trade in interbank markets was perceived as being too costly. Morten Bech responded that the role of monitoring had not been considered in the model presented in the paper, but agreed that interbank monitoring was a positive feature of the corridor system. He suggested, however, that the benefits of monitoring needed to be weighed against the benefits to the payment system that arose from paying interest on reserves; the payment system would be expected to operate more smoothly because reserves were available for use intraday in the payment system, making banks less inclined to delay their payments. Dr Bech demurred from taking a position on which system was optimal since the model's view of unconventional monetary policy was focused on the effects of the asset purchase programs, and did not speak directly to this issue. In addition, Dr Bech noted that the models in the paper did not say anything about the appropriate management of the corridor. He added that intervention had aimed to reduce volatility within the corridor, but the effect of market size on volatility was not yet well understood.

Several participants observed that while the model provided useful insights into the implications of the increase in excess reserves, it did not consider other aspects of unconventional monetary policy, such as forward guidance from the Federal Reserve about its exit from holding non-standard assets. Dr Bech agreed that unconventional monetary policy comprised a much broader set of instruments, but noted that his paper had intentionally restricted its focus to the sharp rise in excess reserves as an endogenous by-product of purchase programs targeting the long end of the yield curve.

One participant raised a potential empirical issue relating to the paper's fourth stylised fact that the rate a bank had to pay in the interbank market tended to rise with its risk of default. The participant cautioned that the average rates charged in the interbank market could be misleading in high-stress situations due to self-selection; where banks were shut out of unsecured funding markets, or faced punitive rates for such funding, they might instead access funding through the secured market or the central bank. Indeed, average interbank rates charged in the euro area had fallen on particularly high-stress days during the crisis. The participant then asked whether banks' choice of funding source could be included in the model. Dr Bech responded that modelling this empirically would require highly disaggregated trade data. He emphasised that an attractive feature of the model was that with sufficiently high credit risk, interbank markets tended to disappear, and this occurred irrespective of the level of excess reserves.

On the Economics of Committed Liquidity Facilities

Morten L Bech and Todd Keister*

1. Introduction

As part of the regulatory response to the recent global financial crisis, the Basel Committee on Banking Supervision (BCBS) announced a new international regulatory framework for banks, known as Basel III. One important component of Basel III is the Liquidity Coverage Ratio (LCR), which aims to ensure that banks hold a more liquid portfolio of assets and rely on the central bank for funding only as a last resort. Specifically, the LCR requires each bank to hold a sufficient quantity of highly liquid assets to survive a 30-day period of market stress; this requirement is scheduled to be phased in gradually beginning in January 2015. In the process of designing and calibrating the LCR rules, it became clear that some jurisdictions do not have sufficient high-quality liquid assets (HQLA) for their banking system to meet this new requirement. Australia and South Africa are cases in point, as both have limited amounts of sovereign debt and other qualifying securities; see Debelle (2011), Heath and Manning (2012) and South African Reserve Bank (2012). In such jurisdictions, the regulation offers the central bank the option of providing, for an up-front fee, contractual committed liquidity lines that count toward a bank's stock of liquid assets. Stein (2013) argues that such lines have the potential to be a useful safety valve in other situations as well, since they can place an upper bound on the cost of the liquidity regulation.

This type of committed liquidity facility (CLF) is an innovation within central banking and raises several interesting questions. How should these facilities be designed and priced? How will they interact with other parts of central banks' missions? Should such facilities be used only in jurisdictions with a shortage of HQLA or should they be part of all central banks' toolkits? With a view to providing a framework for addressing these questions, we develop a model that extends our earlier work on implementing monetary policy in the presence of an LCR requirement (Bech and Keister 2013). We show how the LCR requirement can have significant side effects in a jurisdiction with a limited supply of HQLA, leading to a large regulatory liquidity premium and pushing the short-term interest rate to the floor of the central bank's rate corridor. Introducing a CLF allows the central bank to mitigate these effects, regardless of whether it is implemented as a fixed-price standing facility or using a fixed-quantity auction format. By pricing the CLF appropriately, the central bank can control either the equilibrium liquidity premium or the quantity of liquid assets held by banks, but not both. We argue that the optimal pricing arrangement will need to balance the costs of higher interest rate spreads against the benefits of having more liquid assets in the banking system and will depend on local bond market conditions. Moreover, given the uncertainty about equilibrium relationships in the new regulatory environment, we argue

* The views expressed herein are those of the authors and do not necessarily reflect those of the Bank for International Settlements.

that central banks are likely to want to take a flexible approach to CLF pricing, adjusting terms as more experience is gained with this new policy tool.

We provide a brief overview of the new regulatory framework in the next section, then present our model in Section 3. We derive banks' demand for assets and CLF drawing rights in Section 4 and study equilibrium quantities and interest rates in Section 5. We use the model to discuss CLF pricing and related issues in Section 6 before concluding in Section 7.

2. The Regulatory Framework

In this section, we describe the regulations governing the LCR and the use of CLFs. Our discussion is based on the revised rules issued in January 2013 (BCBS 2013).

2.1 The Liquidity Coverage Ratio (LCR)

The LCR builds on traditional methodologies used internally by banks to assess exposure to contingent liquidity events. The regulation will require that a bank's stock of unencumbered HQLA be larger than its projected net cash outflows (NCOF) over a 30-day horizon under a stress scenario specified by supervisors; that is:

$$\text{LCR} = \frac{\text{Stock of unencumbered high-quality liquid assets}}{\text{Net cash outflows over the next 30 calendar days}} = \frac{\text{HQLA}}{\text{NCOF}} \geq 100 \text{ per cent.} \tag{1}$$

This requirement is scheduled to be phased in gradually, beginning with 60 per cent coverage in January 2015 and rising 10 percentage points each year to reach 100 per cent in January 2019.

Two types (or ' levels') of assets can be counted toward the calculation of HQLA in the numerator of the ratio. Level 1 assets include cash, central bank reserves and certain marketable securities backed by sovereigns and central banks; these assets can be used without limit to meet the requirement. Level 2 assets enter the calculation in a more restricted way and are divided into two subgroups. Level 2A assets include certain government securities, corporate debt securities and covered bonds, while Level 2B assets include lower-rated corporate bonds, residential mortgage-backed securities and equities that meet certain conditions. Level 2A assets can account for a maximum of 40 per cent of a bank's total stock of HQLA, whereas Level 2B assets can account for a maximum of 15 per cent of the total.

The denominator of the ratio, NCOF, is calculated by multiplying the size of various types of liabilities and off-balance sheet commitments by the rates at which they run off or are drawn down in the specified stress scenario. This scenario is designed to include a partial loss of retail deposits, significant loss of wholesale funding, contractual outflows from derivative positions associated with a three-notch ratings downgrade, and substantial calls on off-balance sheet exposures. From these outflows, banks are permitted to subtract expected inflows during the next 30 calendar days. In order to prevent banks from relying solely on anticipated inflows to meet their liquidity requirement, the fraction of outflows that can be offset this way is capped at 75 per cent.

2.2 Committed liquidity facilities (CLFs)

The LCR rules recognise that, in some jurisdictions, the relatively small stock of assets qualifying as HQLA could make implementing the LCR requirement problematic. Debelle (2011) describes the situation in Australia as follows:

> [T]here is a marked shortage of high quality liquid assets that are outside the banking sector (that is, not liabilities of the banks). As a result of prudent fiscal policy over a large run of years at both the Commonwealth and state level, the stock of Commonwealth and state government debt is low. At the moment, the gross stock of Commonwealth debt on issue amounts to around 15 per cent of GDP, state government debt (semis) is around 12 per cent of GDP. These amounts fall well short of the liquidity needs of the banking system.

To address such situations, the BCBS has developed a number of policy options, one of which is for the central bank to operate a CLF.[1] The LCR rules specify that:

> [T]hese facilities are contractual arrangements between the central bank and the commercial bank with a maturity date which, at a minimum, falls outside the 30-day LCR window … Such facilities are only permissible if there is also a fee for the facility which is charged regardless of the amount, if any, drawn down against that facility … (BCBS 2013, paragraph 58).

The Reserve Bank of Australia (RBA) and the South African Reserve Bank (SARB) have both indicated their intention to provide committed liquidity facilities and have published details on how the facilities are to be designed; the term sheets are summarised in Table 1. The two facilities are similar in many respects but differ in some dimensions. In both facilities, the up-front fee is lower than the spread between the rate for the central bank's standing lending facility and the target for the overnight rate. Moreover, both facilities charge banks the overnight lending facility rate for drawdowns and have limits on the usage of the facilities. The set of eligible collateral is larger than what is normally accepted at each central bank's other facilities. One key difference is that the up-front fee is fixed for the RBA but is determined by a progressive scale dependent on the quantity contracted for the SARB.

Table 1: CLF Term Sheets

	Reserve Bank of Australia	South African Reserve Bank
Pricing		
Policy corridor	±25 bps	±100 bps
Up-front fee	fixed (15 bps)	scaled (15–45 bps)
Drawdown rate	= o/n lending facility rate	= o/n lending facility rate
Maximum amount	determined by supervisor	40% of NCOF
Collateral		
Assets eligible	> lending facility	> lending facility
Additional assets	self-securitised RMBS	self-securitised ABS
Haircuts	= other RBA facilities	= other SARB facilities

Notes: RMBS denotes residential mortgage-backed securities, ABS denotes asset-backed securities
Sources: RBA (2013); SARB (2012)

1 The other options are using foreign currency HQLA to cover domestic currency liquidity needs and increasing the use of Level 2 assets with a higher haircut; see BCBS (2013).

3. The Model

The analysis here builds on Bech and Keister (2013), which studies monetary policy implementation in the presence of an LCR requirement.[2] We introduce two new features into this framework: (i) banks' asset portfolios are endogenous rather than fixed; and (ii) the central bank operates a CLF. In this section, we describe the role of banks and of the various markets in the model, as well as the basic design features of the CLF.

3.1 Banks

There is a continuum of identical banks, indexed by $i \in [0,1]$, all of which behave competitively in the sense that they take market interest rates as given and aim to maximise expected profits.

3.1.1 Balance sheets and decisions

The model plays out over the course of a period with four stages. Bank i begins the period with a balance sheet of the form:

Assets		Liabilities	
Loans	L^i	Deposits	$\bar{D}$
Bonds	B^i		
Reserves	R^i	Equity	$\bar{E}$

To simplify the analysis, we take the values of deposits $\bar{D}$ and equity $\bar{E}$ as given; these values are determined by activities outside the scope of the model. In the first stage, banks distribute their fixed resources across the three assets shown in the balance sheet: loans, bonds, and reserves. In the second stage, the central bank offers banks an opportunity to acquire rights to draw funds under its CLF. Let F^i denote the quantity of such rights acquired by bank i, which is an off-balance-sheet item. After the CLF has closed, each bank experiences a payment shock in which an amount ε^i of customer deposits is sent as a payment to another bank. If ε^i is negative, the shock represents an inflow of funds. The value of ε^i is drawn from a common, symmetric distribution G with zero mean. Depending on the size of this shock, a bank may need to borrow from the central bank to meet its regulatory requirements. This borrowing takes place in the fourth and final stage; let $X^i \geq 0$ denote the amount borrowed.[3] Bank i's end-of-period balance sheet is then:

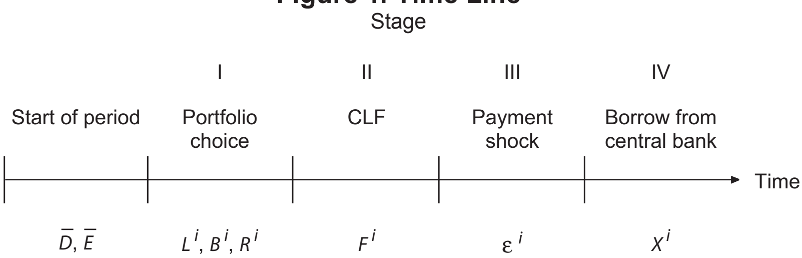
2 Our model is in the tradition of Poole (1968) and many others. Much of this literature focuses on interbank markets and the implementation of monetary policy through open market operations. Our focus here, in contrast, is on how banks' portfolio choices are affected by liquidity regulation.

3 To simplify the presentation, we assume a bank always has sufficient collateral in the form of loans L^i so that it can borrow as much as needed from the central bank to satisfy its regulatory requirements.

Assets		Liabilities	
Loans	L^i	Deposits	$\bar{D}-\varepsilon^i$
Bonds	B^i	Central bank borrowing	X^i
Reserves	$R^i-\varepsilon^i+X^i$	Equity	$\bar{E}$

Figure 1 illustrates the sequence of events and summarises when banks choose each decision variable.

Figure 1: Time Line



3.1.2 The reserve requirement

Each bank faces a reserve requirement of the form:

$$R^i-\varepsilon^i+X^i \geq \bar{K} \equiv 0. \tag{2}$$

The left-hand side of this expression is the bank's reserve holdings at the end of the period, taking into account the payment shock and any borrowing from the central bank. The right-hand side is the requirement for the period. To conserve on notation, we study a system with no reserve requirements by setting $\bar{K}$ to zero, so that Equation (2) simply requires each bank to avoid an overdraft in its reserve account at the end of the period. If the bank were to violate this requirement after the realisation of the payment shock, it would borrow funds from the central bank to ensure that Equation (2) held.

3.1.3 The LCR requirement

In the context of our model, bank *i*'s LCR requirement is:

$$LCR^i=\frac{B^i+R^i-\varepsilon^i+X^i+F^i}{\theta\left(\bar{D}-\varepsilon^i\right)} \geq 100\%. \tag{3}$$

Recall from Equation (1) that the numerator of the ratio is the total value of the bank's HQLA (its end-of-period holdings of bonds and reserves) plus any rights to draw on the CLF it has purchased. The denominator measures the 30-day NCOF assumed under the stress scenario, which in our model equals a fraction $\theta > 0$ of the bank's deposits.[4] Notice that contracting with the CLF (increasing F^i) has the same effect on a bank's LCR as holding more bonds (increasing B^i).

3.1.4 Bank profits

The bank earns the interest rates r_L and r_B on its loans and bond holdings, respectively, and pays an interest rate r_D on customer deposits. The bank pays the central bank ϕ per unit of CLF rights purchased. It earns r_R on any positive reserve balances and faces a penalty rate $r_X > r_R$ for any funds borrowed from the central bank's overnight lending facility.

In comparing interest rates across assets, differences in credit risk and liquidity risk are clearly important. To account for these differences, we introduce a fixed premium τ that reflects both the credit and liquidity risk associated with loans in our model, so that the risk-adjusted benefit to the bank of making a unit of loans is given by $r_L - \tau$. We assume that bonds and reserves are both short-term, risk-free assets and, hence, the premium associated with these assets is zero.[5] Bank i's profit for the period, net of credit and liquidity risk, can then be written as:

$$\pi^i\left(\varepsilon^i\right) = \left(r_L - \tau\right)L^i + r_B B^i - r_D\left(\bar{D} - \varepsilon^i\right) - \phi F^i + r_R \max\left\{R^i + X^i - \varepsilon^i, 0\right\} - r_X X^i . \qquad (4)$$

Note that the quantity of CLF rights purchased affects two terms in this expression: it creates an expense of ϕF^i and it potentially decreases the amount X^i of borrowing from the central bank.

3.2 Markets

To help maintain tractability, we assume that the markets in which banks trade in Stage I of Figure 1 are competitive and operate without frictions. We assume the loan market is completely passive – banks can make whatever quantity of loans they want at the equilibrium interest rate r_L^*. We describe the markets for reserves and bonds below.

3.2.1 The market for reserves

The central bank determines the total supply of reserves $\bar{R}$ at the beginning of the period.[6] To simplify our analysis, we assume the central bank sets the supply of reserves equal to total required reserves, which implies:

$$\bar{R} = \bar{K} = 0.$$

4 The LCR rules assign a minimum run-off rate of either 3 per cent or 5 per cent to retail deposits covered by an effective deposit insurance scheme. Retail deposits deemed to be less stable are assigned a minimum run-off rate of 10 per cent; see BCBS (2013) for more detail. Secured transactions with the central bank are assigned a 0 per cent run-off rate. However, the LCR is a minimum standard; hence local authorities can set a higher value for these run-off rates at their discretion. See Bech and Keister (2013) for an analysis of the effects of an LCR requirement when loans from the central bank are assigned a positive run-off rate.

5 The bonds in our model should, therefore, be interpreted as short-term bills. It would be straightforward to include long-term bonds that carry a term premium; what matters for our analysis is the spread between the interest rates on loans and bonds after accounting for risk and term premia.

6 We do not explicitly model open market operations here, but any operations can be thought of as taking place in the market where bonds are bought and sold in Stage I of Figure 1. See Bech and Keister (2013) for a detailed study of the effects of open market operations in the presence of an LCR constraint.

In an environment with no LCR requirement, this policy would steer the overnight interest rate to the midpoint of the central bank's corridor $[r_R, r_X]$ in the standard way (see, for example, Whitesell (2006)). We denote this midpoint by

$$\bar{r} \equiv \frac{r_X + r_R}{2} \tag{5}$$

and note that, in the absence of an LCR requirement, $\bar{r}$ would be the risk-free, short-term interest rate in the economy.

3.2.2 The bond market

An important goal of our model is to determine how the quantity of bonds held by banks depends on the LCR requirement and on the design features of the CLF. Any bonds not held by banks are held by non-bank entities, including other financial institutions, households and foreign entities. We assume that the total quantity of bonds in the economy is fixed at $\bar{B}$ and that the demand for bonds by non-bank entities is a continuous, weakly increasing function of the interest rate r_B. As a result, the supply of bonds to the banking sector – that is, the quantity of bonds not held by non-banks – is a continuous, weakly decreasing function of r_B. We denote this supply function by $\mu(B)$. While we allow this function to take many different shapes, we impose one regularity condition to simplify the analysis:

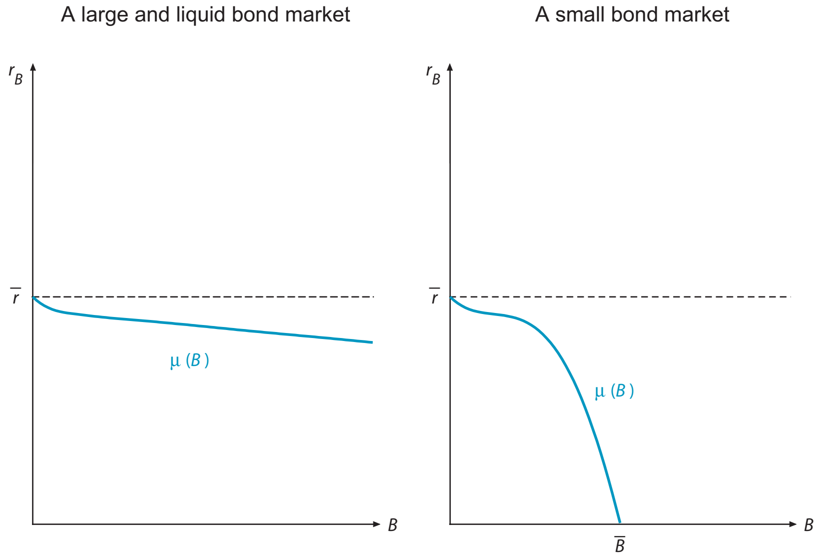
$$\mu(0) = \bar{r}. \tag{6}$$

This condition states that if all bonds are held outside the banking system, their interest rate will equal the midpoint of the central bank's interest rate corridor. It implies that, in the absence of an LCR requirement, bonds would earn the same rate of return as other risk-free assets.[7]

Figure 2 depicts two different bond supply functions. In the left-hand panel, the bond market is both large and liquid in the sense that banks' purchases of bonds have relatively little effect on their price. In this situation, the interest rate on bonds remains close to $\bar{r}$ over a wide range of bond holdings by banks. The right-hand panel, in contrast, depicts a situation in which the total quantity of bonds $\bar{B}$ is much smaller and the demand for bonds by non-banks is inelastic in some regions. This panel captures important features of the market for government bonds in jurisdictions like Australia where, according to Davis (2011, p 5), '[a]s banks attempt to increase their holdings of government debt, their demand will drive down its yield relative to other investments'. Debelle (2013) adds that '[a]t some point, the scarcity of available [government debt] securities would cause their yields to fall to a particularly low level'. In the analysis below, we show how the effect of introducing an LCR requirement depends crucially on the shape of the bond supply function μ, which may vary over time as well as across countries.

7 In general, bonds may yield a lower return than other risk-free assets because they provide additional, non-pecuniary services. These services can be especially valuable for non-bank entities, which cannot hold reserves and may value bonds for liquidity or hedging purposes, or for currency diversification.

Figure 2: Supply of Bonds to the Banking System



3.3 The committed liquidity facility (CLF)

In general terms, the design of the CLF is characterised by a non-decreasing price function $\phi(F)$ that specifies the fee the central bank will charge for CLF rights if the total quantity of rights purchased by all banks is F. We assume that CLF rights are allocated in a competitive fashion, meaning that each bank takes the fee ϕ as given when choosing the quantity of rights to purchase. Our model can be generalised to allow for non-competitive allocation rules or for pricing rules in which each bank faces an increasing fee schedule depending on the amount borrowed, but we restrict our attention to the simpler, linear case here.

We focus on two specific designs for the CLF. The first is a fixed-price standing facility in which each bank can purchase as many CLF rights as it wants at a given price $\bar{\phi}$; this design corresponds to setting $\phi(F)=\bar{\phi}$ for all F. The second design we consider is a fixed-quantity auction, where the central bank offers a quantity $\bar{F}$ of CLF rights and is willing to accept whatever fee emerges from the auction. In the analysis below, we show that these two designs lead to equivalent outcomes in our model.

4. Optimal Portfolio Choices

In this section, we derive a typical bank's demand for each of the three assets and for CLF rights. We begin with Stage IV in the time line in Figure 1, where each bank determines how much to borrow from the central bank's standing facility at the end of the period. This borrowing rule allows us to derive a bank's expected profit before the payment shock is realised, which is the objective the bank seeks to maximise when making its decisions in Stages I and II.

4.1 Borrowing from the central bank

Borrowing from the central bank is costly and, therefore, each bank will choose to borrow the minimum amount needed to meet its regulatory requirements. Let X_K^i denote the minimum amount bank *i* must borrow from the central bank to fulfill the reserve requirement in Equation (2):

$$X_K^i \equiv \max\left\{\varepsilon^i - R^i, 0\right\}. \tag{7}$$

Let X_C^i denote the minimum amount bank *i* must borrow to fulfill the LCR requirement in Equation (3):

$$X_C^i \equiv \max\left\{(1-\theta)\varepsilon^i + \theta\bar{D} - B^i - R^i - F^i, 0\right\}. \tag{8}$$

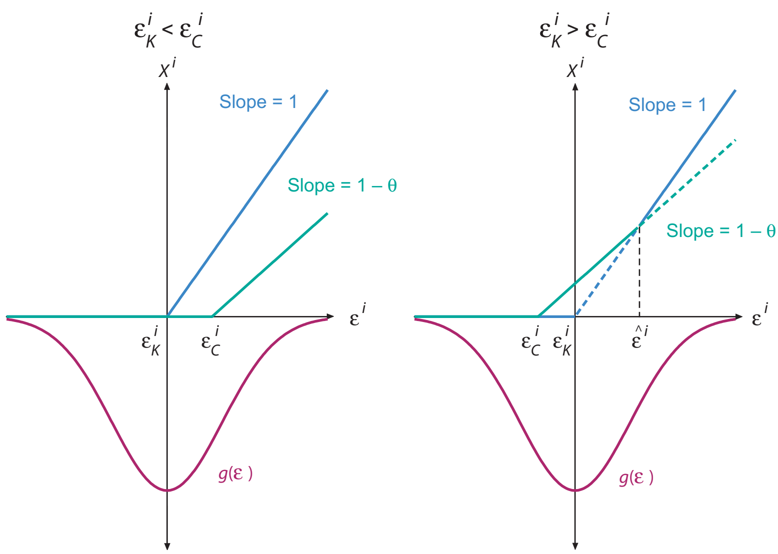
Bank *i*'s total borrowing from the central bank X^i will be the minimum amount needed to fulfill both of these requirements; that is:

$$X^i = \max\left\{X_K^i, X_C^i\right\}. \tag{9}$$

Figure 3 depicts X^i as a function of the realised payment shock ε^i together with a density function *g* for this shock. The light blue curve in each panel represents Equation (7), the borrowing needed to satisfy the reserve requirement, which is positive whenever ε^i is larger than

$$\varepsilon_K^i \equiv R^i. \tag{10}$$

Figure 3: Bank *i*'s Borrowing from the Central Bank Lending Facility



The green curve represents Equation (8), the borrowing needed to satisfy the LCR requirement, which is positive for values of ε^i larger than:

$$\varepsilon_C^i \equiv \frac{B^i + R^i + F^i - \theta\bar{D}}{1-\theta}. \tag{11}$$

The bank's borrowing X^i is the upper envelope of these two curves.

As Figure 3 shows, two distinct cases arise. In the left-hand panel of Figure 3, the elements of the bank's balance sheet are such that $\varepsilon_K^i < \varepsilon_C^i$. In this case, the borrowing needed to satisfy the bank's reserve requirement is always sufficient to ensure that the bank also satisfies its LCR requirement, even when ε^i is larger than ε_C^i. In other words, the amount borrowed from the central bank's lending facility is determined solely by the bank's need to meet its reserve requirement in this case; the LCR requirement is never a binding concern. In contrast, the right-hand panel depicts a situation where the balance sheet is such that $\varepsilon_K^i > \varepsilon_C^i$ holds. In this case, the amount borrowed from the central bank is determined by the need to meet the LCR requirement if ε^i falls in the interval $(\varepsilon_C^i, \hat{\varepsilon}^i)$, where

$$\hat{\varepsilon}^i \equiv \frac{\theta\bar{D}^i - B^i - F^i}{\theta}. \tag{12}$$

and by the need to meet the reserve requirement when ε^i is larger $\hat{\varepsilon}^i$.

4.2 Expected profit

The expected value of bank i's profit defined in Equation (4) can, using $E[\varepsilon^i] = 0$ and rearranging terms, be written as:

$$E\left[\pi^i\right] = (r_L - \tau)L^i + r_B B^i - r_D\bar{D} - \phi F^i + r_R R^i - (r_X - r_R)E\left[X^i\right].$$

Using the definition of X^i in Equation (9), we can rewrite this expression as

$$\begin{aligned} E\left[\pi^i\right] = {} & (r_L - \tau)L^i + r_B B^i - r_D\bar{D} - \phi F^i + r_R R^i \\ & -(r_X - r_R)\left\{\mathbb{I}_{\{\varepsilon_C^i < \varepsilon_K^i\}} \int_{\varepsilon_C^i}^{\hat{\varepsilon}^i} \left((1-\theta)\varepsilon^i + \theta\bar{D} - B^i - R^i - F^i\right) dG\left(\varepsilon^i\right) + \int_{\max\{\varepsilon_K^i, \hat{\varepsilon}^i\}}^{\infty} \left(\varepsilon^i - R^i\right) dG\left(\varepsilon^i\right)\right\}, \end{aligned} \tag{13}$$

where the indicator function $\mathbb{I}_{\{\cdot\}}$ takes the value one if the expression {.} is true and zero otherwise. In making its decisions in Stages I and II of Figure 1, bank i will aim to maximise the value of Equation (13). We derive the optimal choices in each of these stages below.

4.3 The demand for bonds and reserves

In Stage I, bank i divides its initial resources from deposits and equity between loans, bonds and reserves, subject to the balance sheet constraint:

$$L^i + B^i + R^i \leq \bar{D} + \bar{E}. \tag{14}$$

We use this constraint to replace L^i in Equation (13) and focus on the choices of B^i and R^i. To account for the indicator function in this objective function, we look at the first-order conditions separately in two distinct regions of the feasible set.

First, consider values of (B^i, R^i) such that $\varepsilon^i_C < \varepsilon^i_K$, which corresponds to the situation in the right-hand panel of Figure 3. In this region, the indicator function is one, we have $\max\left\{\varepsilon^i_K, \hat{\varepsilon}^i\right\} = \hat{\varepsilon}^i$, and the first-order conditions that characterise a solution are[8]

$$\frac{\partial E\left[\pi^i\right]}{\partial B^i} = -\left(r_L - \tau\right) + r_B + \left(r_X - r_R\right)\left(G\left[\hat{\varepsilon}^i\right] - G\left[\varepsilon^i_C\right]\right) = 0 \tag{15}$$

and

$$\frac{\partial E\left[\pi^i\right]}{\partial R^i} = -\left(r_L - \tau\right) + r_R + \left(r_X - r_R\right)\left(1 - G\left[\varepsilon^i_C\right]\right) = 0. \tag{16}$$

Equation (15) says the marginal income lost from holding bonds instead of loans, $r_L - \tau - r_B$, must equal the marginal benefit bonds provide in meeting the LCR requirement. When ε^i falls in the interval $(\varepsilon^i_C, \hat{\varepsilon}^i)$, holding an extra dollar's worth of bonds allows the bank to borrow one dollar less from the central bank, saving it the net cost $(r_X - r_R)$. Similarly, Equation (16) states that the marginal income lost from holding reserves, $r_L - \tau - r_R$, is equal to the marginal benefit reserves provide in terms of meeting both the LCR requirement and the reserve requirement. As shown in the right-hand panel of Figure 3, holding an additional dollar of reserves allows the bank to borrow one dollar less from the central bank whenever the payment shock is larger than ε^i_C.

Next, consider the region where $\varepsilon^i_C \geq \varepsilon^i_K$, which corresponds to the left-hand panel of Figure 3. In this case, the value of the indicator function is zero, we have $\max\left\{\varepsilon^i_K, \hat{\varepsilon}^i\right\} = \varepsilon^i_K$, and the first-order conditions are

$$\frac{\partial E\left[\pi^i\right]}{\partial B^i} = -\left(r_L - \tau\right) + r_B = 0 \tag{17}$$

and

$$\frac{\partial E\left[\pi^i\right]}{\partial R^i} = -\left(r_L - \tau\right) + r_R - \left(r_X - r_R\right)\left(1 - G\left[\varepsilon^i_K\right]\right) = 0. \tag{18}$$

Notice that Equation (17) implies $r_L - \tau = r_B$ must hold for the solution of the bank's problem to fall in this region. Since the LCR requirement is never a binding concern in this region, Equation (18) implies that the lost income from holding reserves instead of loans, $r_L - \tau - r_R$, must equal the marginal benefit reserves provide simply in terms of meeting the reserve requirement. The following proposition combines these two cases and characterises the bank's optimal portfolio choice in Stage I of Figure 1.

Proposition 1. *Bank i will choose (B^i,R^i) so that the critical values $(\varepsilon^i_K, \varepsilon^i_C, \hat{\varepsilon}^i)$ defined in Equations (10) to (12) satisfy*

$$r_B = r_R + \left(r_X - r_R\right)\left(1 - G\left[\max\left\{\hat{\varepsilon}^i, \varepsilon^i_K\right\}\right]\right) \tag{19}$$

and

$$r_L = r_R + \left(r_X - r_R\right)\left(1 - G\left[\min\left\{\varepsilon^i_C, \varepsilon^i_K\right\}\right]\right) + \tau. \tag{20}$$

8 To simplify the presentation, we allow banks to short sell both loans and bonds and to run overdrafts in their reserve accounts in this stage, which implies there are no non-negativity constraints on this choice problem. In equilibrium, interest rates will be such that banks always choose to hold non-negative amounts of each asset.

4.4 The demand for CLF rights

In Stage II of Figure 1, bank *i* will choose to purchase a quantity $F^i \geq 0$ of CLF rights, again with the objective of maximising Equation (13). In the region where $\varepsilon_C^i < \varepsilon_K^i$, the first-order condition characterising the optimal choice is

$$\frac{\partial E\left[\pi^i\right]}{\partial F^i} = -\phi + \left(r_X - r_R\right)\left(G\left[\hat{\varepsilon}^i\right] - G\left[\varepsilon_C^i\right]\right) \leq 0$$

with equality if $F^i > 0$. In this region, which again corresponds to the right-hand panel in Figure 3, purchasing CLF rights helps mitigate the bank's LCR shortfall when the realisation of the payment shock is between ε_C^i and $\hat{\varepsilon}^i$. Notice the similarity between this condition and Equation (15), which reflects the fact that holding bonds and purchasing CLF rights offer the same benefit in terms of increasing the bank's LCR. The bank will choose to purchase CLF rights only if the fee ϕ is no larger than the income loss associated with holding bonds, $r_L - \tau - r_B$.

In the region where $\varepsilon_C^i \geq \varepsilon_K^i$, the marginal benefit of CLF rights is given by

$$\frac{\partial E\left[\pi^i\right]}{\partial F^i} = -\phi,$$

which is always negative. This region again corresponds to the left-hand panel in Figure 3, where the LCR is never a binding concern and, as a result, CLF rights have no value for the bank. If the solution to the bank's optimisation problem lies in this region, it will necessarily have $F^i = 0$. The following proposition formalises these results.

Proposition 2. *Bank i's demand for CLF rights is given by:*

$$F^i = \begin{Bmatrix} 0 \\ \in[0,\infty) \\ \infty \end{Bmatrix} \qquad \text{if} \qquad \phi \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} r_L - \tau - r_B .$$

This result shows a tight relationship between the CLF fee ϕ and the opportunity cost of holding bonds, $r_L - \tau - r_B$. If purchasing CLF rights is more expensive than holding bonds, banks will not use the CLF. If purchasing CLF rights is cheaper than holding bonds, banks will demand as many CLF rights as possible, selling bonds to compensate. In the middle case, banks are indifferent at the margin between holding bonds and purchasing CLF rights for the purpose of satisfying the LCR requirement.

5. Equilibrium

In this section, we derive the equilibrium interest rates and portfolio choices. After providing a formal definition of equilibrium, we analyse outcomes in a benchmark setting with no liquidity regulation, then in a setting with an LCR requirement but no CLF, and finally in a setting where a CLF is introduced.

5.1 Definition

Since there is a unit measure of banks, all of whom face the same decision problem, the aggregate demand for loans, bonds, reserves and CLF rights are the same as the individual demands derived above. Equilibrium requires that each of these demands equals the corresponding supply of the asset to the banking system, as specified in the following definition.

Definition: *An equilibrium consists of a portfolio choice for banks (L^*, B^*, R^*, F^*) together with interest rates (r_L^*, r_B^*) and a CLF fee ϕ^* such that:*

(i) each bank's choices (L^*, B^*, R^*, F^*) maximise its expected profit (Equation (13)) subject to the balance sheet constraint in Equation (14), taking the interest rates and CLF fee as given

(ii) markets clear, that is

$$B^* = \mu^{-1}\left(r_B^*\right) \qquad \text{and} \qquad R^* = \overline{R} = 0 \tag{21}$$

(iii) CLF rights are priced according to the central bank's rule,

$$\phi^* = \phi\left(F^*\right).$$

Using the market-clearing conditions in Equation (21), we can write the equilibrium values of the critical points for the payment shock defined in Equations (10) to (12) as:

$$\varepsilon_K^* = 0, \qquad \varepsilon_C^*\left(B^* + F^*\right) = \frac{B^* + F^* - \theta\overline{D}}{1-\theta} \quad \text{and} \quad \hat{\varepsilon}^*\left(B^* + F^*\right) = -\frac{\left(B^* + F^* - \theta\overline{D}\right)}{\theta}. \tag{22}$$

Note that ε_K^* depends only on the central bank's choice for the quantity of excess reserves, which we have assumed to be zero. In contrast, both ε_C^* and $\hat{\varepsilon}^*$ are functions of the sum of banks' bond holdings and CLF rights, $B^* + F^*$, which is determined as part of the equilibrium.

5.2 Equilibrium with no liquidity regulation

We begin by studying the properties of equilibrium in a benchmark case where there is no liquidity regulation, which corresponds to setting the run-off rate θ in our model to zero. In this case, the critical values in Equation (22) will always satisfy $\varepsilon_C^* \geq \varepsilon_K^* = 0$ and, hence, the configuration is always like that in the left-hand panel of Figure 3. In other words, when there is no LCR requirement, banks' only liquidity management concern in our model is satisfying the reserve requirement in Equation (2). The following proposition characterises the equilibrium outcome in this case.

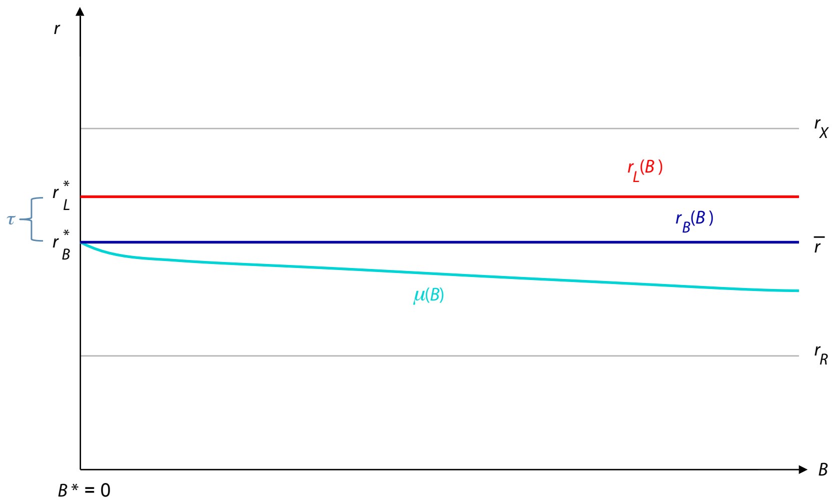
Proposition 3. *When there is no LCR requirement, equilibrium interest rates satisfy:*

$$r_L^* - \tau = r_B^* = \overline{r}.$$

When there is no liquidity regulation, the short-term, risk-free interest rate equals the midpoint of the central bank's corridor, $\overline{r}$, as in Whitesell (2006) and others. The interest rate on loans is given by $r_L^* = \overline{r} + \tau$, which implies that the premium τ can be interpreted as the market price of credit and liquidity risk.

Figure 4 illustrates this result. The dark blue line in Figure 4 corresponds to banks' demand for bonds from Equation (19). When there is no LCR requirement, this equation simply says that banks are willing to hold bonds only if the return they offer is at least equal to the risk-free rate. For this reason, the demand curve is flat at $\overline{r}$. Similarly, the red line represents banks' demand for loans from Equation (20). Since banks are willing to hold loans only if the net return $r_L - \tau$ is at least equal to the market risk-free rate, this demand curve is flat at $\overline{r} + \tau$. The light blue curve represents the supply of bonds to the banking system $\mu(B)$. Equilibrium occurs when this supply curve crosses the dark blue demand curve, which happens here at $B^* = 0$. In other words, given this particular function μ, banks will hold no bonds in equilibrium in the absence of liquidity regulation.[9]

Figure 4: Equilibrium with No Liquidity Regulation



To the extent that holdings of liquid assets by banks provide external benefits, it might be desirable to introduce liquidity regulation to the situation depicted in Figure 4. One can think of the objective of such regulation as being twofold: (i) encouraging banks to hold a more liquid portfolio of assets; and (ii) correcting the possible underpricing of liquidity risk in markets. Stein (2013) puts it this way:

> [A]s the financial crisis made painfully clear, the business of liquidity provision inevitably exposes financial intermediaries to various forms of run risk … [F]ire sales and bank failures – and the accompanying contractions in credit availability – can have spillover effects to other financial institutions and to the economy as a whole. Thus, while banks will naturally hold buffer stocks of liquid assets to handle unanticipated outflows, they may not hold enough because, although they bear all the costs of this buffer stocking, they do not capture all of the social benefits, in terms of enhanced financial stability and lower costs to taxpayers in the event of failure. It is this externality that creates a role for policy.

An LCR requirement is one policy tool that can be used to address these issues.

5.3 Equilibrium with an LCR requirement

We now study how the equilibrium changes when banks are subject to the LCR requirement in Equation (3) with a run-off rate on deposits of $\theta > 0$, but there is no CLF. The following proposition characterises the equilibrium outcome.

9 The result that banks hold zero bonds in this situation arises, in part, because we have assumed that banks receive no liquidity or other services from holdings bonds, whereas non-bank entities do. Alternatively, one could interpret B^* as being banks' bond holdings beyond those used in its normal course of business, for example as collateral for settlement purposes.

Proposition 4. *When there is an LCR requirement but no CLF, equilibrium bond holdings B* are implicitly defined by*

$$\mu(B^*) = r_R + (r_X - r_R)\left(1 - G\left[\hat{\varepsilon}^*(B^*)\right]\right)$$

and equilibrium interest rates satisfy

$$r_L^* = r_R + (r_X - r_R)\left(1 - G\left[\varepsilon_C^*(B^*)\right]\right) + \tau$$

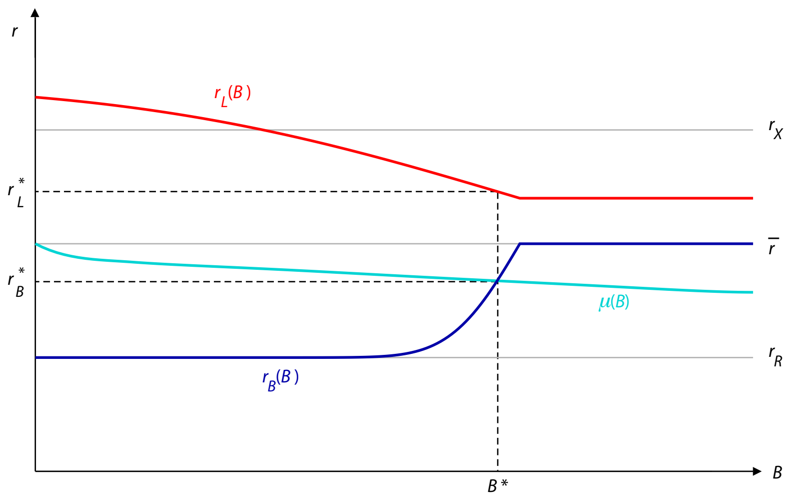
and

$$r_B^* = \mu(B^*).$$

This result and its implications are illustrated in Figure 5. The dark blue curve again corresponds to banks' demand for bonds from Equation (19), which we rewrite here as an explicit function of B using the equilibrium critical points in Equation (22) with F^* set to zero,

$$r_B = r_R + (r_X - r_R)\left(1 - G\left[\max\left\{\hat{\varepsilon}^*(B), 0\right\}\right]\right). \tag{23}$$

Figure 5: Equilibrium with an LCR but No CLF



When banks' bond holdings are low, $\hat{\varepsilon}^*$ is positive and the curve is an increasing function of B. Once the level of bond holdings reaches $\theta\bar{D}$, however, banks are holding enough bonds to ensure that the LCR requirement is never a binding concern. Beyond this point, banks are willing to hold additional bonds only when the yield is at least $\bar{r}$. Similarly, using Equations (20) and (22), we can write the relationship between the loan rate r_L and the quantity of bonds held by banks as

$$r_L = r_R + (r_X - r_R)\left(1 - G\left[\min\left\{\varepsilon_C^*(B), 0\right\}\right]\right) + \tau. \tag{24}$$

This relationship corresponds to the red curve in Figure 5. When B is less than $\theta\bar{D}$, ε_C^* is negative and the curve lies above the rate $\bar{r}$. As B increases, the likelihood of an LCR deficiency falls and, therefore, the spread between the loan rate and $\bar{r}$ gradually declines, reaching τ at $B = \theta\bar{D}$.

Equilibrium is determined by the intersection of the demand curve in Equation (23) with the supply curve for bonds $\mu(B)$, which is again represented by the light blue curve in Figure 5. Equilibrium bond holdings are denoted by B^* and the equilibrium interest rate on bonds by r_B^*. The equilibrium loan rate is determined by the corresponding point on the red curve, denoted r_L^*. Notice that once an LCR requirement is introduced, we have the strict ordering:

$$r_L^* - \tau > \bar{r} > r_B^* .$$

In other words, the LCR requirement raises the equilibrium loan rate r_L^* while lowering the equilibrium interest rate on bonds r_B^*.[10] The spread $r_L^* - r_B^*$ now has two components: the original premium τ is augmented by a regulatory liquidity premium that reflects the equilibrium value banks place on bonds for the purposes of meeting the LCR requirement. Using Equations (23) and (24), we can write this spread as:

$$r_L^* - r_B^* = \tau + \left(r_X - r_R\right)\left(G\left[\hat{\varepsilon}^*\right] - G\left[\varepsilon_C^*\right]\right) \equiv \tau + p^* . \tag{25}$$

The regulatory liquidity premium, denoted p^*, equals the probability of the LCR being a binding concern for each bank (see the right-hand panel of Figure 3) multiplied by the net cost of borrowing an additional dollar from the central bank to meet this requirement. Note that while the additional premium raises the cost of credit – that is, loans in the economy – this outcome may be desirable if liquidity was thought to be underpriced before the regulation was put in place.

Figure 6 depicts the effects of an LCR requirement for an economy with a more limited supply of bonds. The increase in banks' bond holdings generated by the regulation is necessarily much smaller in this case than in Figure 5, while the increase in the spread $r_L^* - r_B^*$ is much larger. In fact, banks' demand to hold bonds for LCR purposes in this case pushes the equilibrium interest rate on bonds down to the floor of the central bank's corridor at r_R. The scarcity of bonds in the economy implies that banks will often find themselves facing an LCR deficiency and, hence, needing to borrow reserves from the central bank to meet this requirement. These borrowed reserves perform double duty in the sense that they count toward both a bank's LCR requirement and its reserve requirement. As a result of this borrowing, therefore, banks become virtually certain to over-satisfy their reserve requirements, which implies that bonds and reserves become near-perfect substitutes. In other words, introducing an LCR requirement in this economy causes the short-term interest rate to fall and thereby affects the implementation of monetary policy. In effect, the central bank in this scenario ends up operating a 'floor system' of monetary policy implementation.[11] Debelle (2011) discusses these concerns:

> [O]ne possible solution to the shortage of level 1 assets would be for banks to significantly increase the size of their [reserve holdings] to meet their liquidity needs. While this is possible, it would mean that the RBA's balance sheet would increase considerably. The RBA would have to determine what assets it would be willing to hold against the increase in its liabilities, and would be confronted by the same problem of the shortage of assets in Australia outside the banking system.

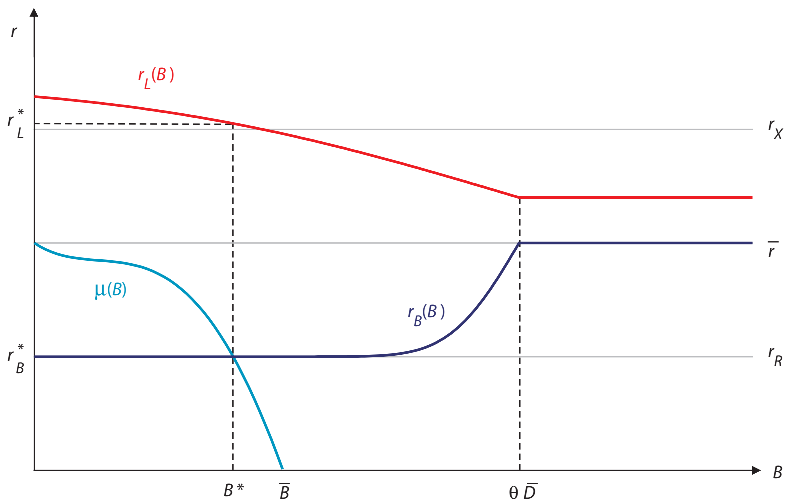
10 These results mirror those in Bech and Keister (2013), which shows how an LCR requirement tends to raise the interest rate on interbank loans with maturities outside the 30-day LCR window, while lowering the rate on shorter maturity loans.

11 See Goodfriend (2002) and Keister, Martin and McAndrews (2008) for discussions of the floor system of monetary policy implementation.

> … [T]his outcome would also significantly affect the ability to meet the cash rate target set by the Reserve Bank Board. That is, we do not want to impair the operational framework for monetary policy which has served us well for many years.

It is precisely to mitigate these problems that the LCR rules permit central banks in certain jurisdictions to operate a CLF.

Figure 6: Equilibrium with No CLF and a Small Supply of Bonds



5.4 Equilibrium with a CLF

We now ask how the equilibrium of the model changes when the central bank introduces a committed liquidity facility. The facility is characterised by a non-decreasing price function $\phi(F)$ as described in Section 3.3. We first show that if the fee for CLF rights is set sufficiently high, banks do not use the facility and the equilibrium outcome is the same as when there is no CLF.

Proposition 5. *If $\phi(0) \geq p^*$, the CLF is not used in equilibrium, $F^* = 0$. Equilibrium bond holdings B^* and interest rates (r_L^*, r_B^*) are as given in Proposition 4.*

Recall that p^*, as defined in Equation (25), represents the regulatory liquidity premium that arises in the absence of a CLF. If the fee for purchasing CLF rights is larger than this premium, it would be less expensive for a bank to increase its LCR by holding more bonds and fewer loans than by using the CLF. In such a situation, the CLF will see no activity. The next proposition characterises how the equilibrium allocation changes when the CLF is priced in a way that attracts usage.

Proposition 6. *If $\phi(0) < p^*$, then the equilibrium quantities (B^*, F^*) are defined by*

$$\mu(B^*) = r_R + (r_X - r_R)\left(1 - G\left[\hat{\varepsilon}^*(B^* + F^*)\right]\right) \tag{26}$$

and

$$\phi(F^*) = (r_X - r_R)\left(G\left[\hat{\varepsilon}^*(B^* + F^*)\right] - G\left[\varepsilon_C^*(B^* + F^*)\right]\right). \tag{27}$$

The equilibrium interest rates and CLF fee satisfy

$$r_L^* = r_R + (r_X - r_R)\left(1 - G\left[\varepsilon_C^*(B^* + F^*)\right]\right) + \tau, \tag{28}$$

$$r_B^* = \mu(B^*) \tag{29}$$

and

$$\phi^* = \phi(F^*). \tag{30}$$

Equation (26) requires that the supply of bonds to the banking system equal banks' demand for bonds, taking into account the fact that this demand depends on CLF usage F^*. Equation (27) requires that the CLF fee equals the size of the regulatory liquidity premium that arises in equilibrium, which ensures that banks are willing to use the facility.

As discussed above, banks can increase their stock of HQLA either by holding more bonds or by holding loans and purchasing CLF rights. The net yield from the latter approach is given by the net yield on loans, $r_L^* - \tau$, minus the CLF fee ϕ^*. Using Equations (27), (28) and (30), we can write this yield as

$$r_L^* - \tau - \phi^* = r_R + (r_X - r_R)\left(1 - G\left[\hat{\varepsilon}^*(B^* + F^*)\right]\right),$$

which, from Equations (26) and (29), is exactly r_B^*. In other words, these two ways of increasing a bank's HQLA must generate the same return. This result relates to the rules on CLF pricing, which state:

> … the fee [should be] set so that banks which claim the facility line to meet the LCR, and banks which do not, have similar financial incentives to reduce their exposure to liquidity risk. That is, the fee should be set so that the net yield on the assets used to secure the facility should not be higher than the net yield on a representative portfolio of Level 1 and Level 2 assets, after adjusting for any material differences in credit risk. (BCBS 2013, paragraph 58)

Proposition 6 shows that, at least in our model environment, when the CLF is active the fee ϕ^* will *always* be such that these two net yields are equal, because the equilibrium returns on assets will necessarily adjust so that this relationship holds.

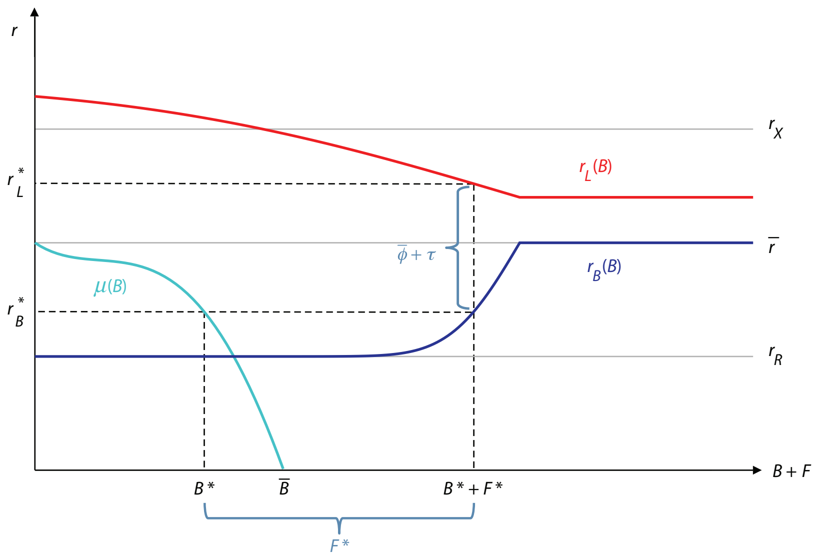
Next, we illustrate the results from Proposition 6 in more detail by studying particular forms of the CLF pricing function $\phi(F)$.

5.4.1 A fixed-price standing facility

Suppose the central bank sets $\phi(F) = \bar{\phi}$ for all F, thereby operating the CLF as a standing facility in which banks can purchase as many rights as they choose at a fixed per-unit fee. Figure 7 illustrates the equilibrium outcome under this type of facility. Recall from Equation (22) that the equilibrium critical values of the payment shock $(\varepsilon_C^*, \hat{\varepsilon}^*)$ – and hence the demand curve in Equation (23) – now depend on the *sum* of the bank's holdings of bonds and CLF rights:

$$r_B = r_R + (r_X - r_R)\left(1 - G\left[\max\left\{\hat{\varepsilon}^*(B + F), \varepsilon_K^*\right\}\right]\right).$$

Figure 7: Equilibrium with a Fixed-price CLF



The dark blue curve in Figure 7 is thus the same as in Figures 5 and 6, but the variable being measured on the horizontal axis is now $B + F$ rather than B alone. Similarly, the red curve has the same shape as in the earlier figures, but now relates the loan rate r_L to the sum $B + F$.

Combining Equations (26) to (30) shows that

$$\bar{\phi}+\tau=r_L^*-r_B^* \tag{31}$$

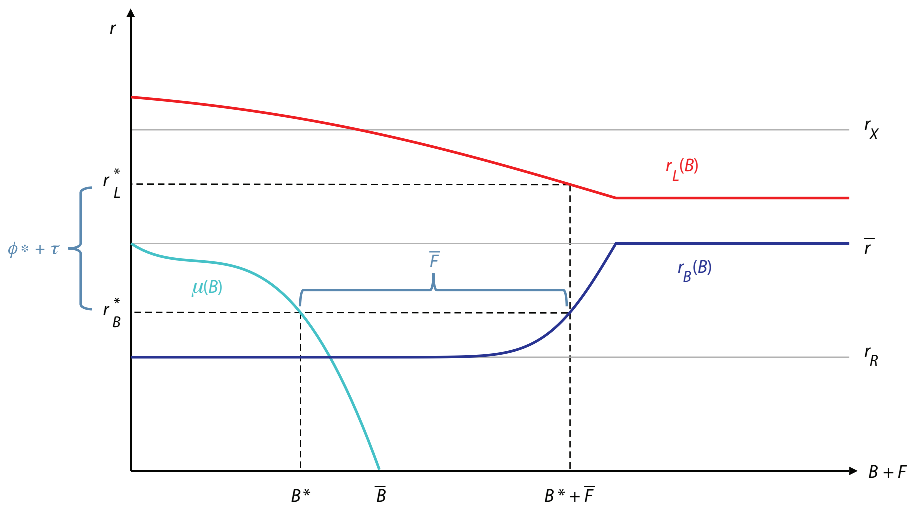
must hold in equilibrium. As shown in Figure 7, there is a unique value of $B + F$ such that the gap between the red and dark blue curves is exactly $\bar{\phi}+\tau$. Equation (31) thus determines the equilibrium sum $B^* + F^*$ and the equilibrium interest rates r_L^* and r_B^*. The equilibrium quantity of bonds held by banks, B^*, is then determined by the supply of bonds $\mu(B)$ at the interest rate r_B^*, as required by Equation (29). The quantity of CLF rights purchased from the standing facility in equilibrium is equal to the difference between the demand for $B + F$ (the dark blue curve in Figure 7) and the supply of B (the light blue curve) at the interest rate r_B^*.

Several interesting results can be seen in Figure 7. First, setting the CLF fee allows the central bank to control the regulatory liquidity premium directly, regardless of the bond supply function μ. Even if the function μ were changing over time or unknown to the central bank, the chosen value of $\bar{\phi}$ would always determine this premium as shown in Equation (31). Second, Figure 7 shows there is a crowding out effect: when $\bar{\phi}$ is set lower, banks purchase more CLF rights but hold fewer bonds. The size of this effect is determined by the shape of the bond supply function μ. In regions where the supply of bonds is relatively elastic (i.e. the light blue curve is relatively flat), a small decrease in $\bar{\phi}$ will lead to a large decrease in B^*. Conversely, in regions where bond supply is inelastic, the crowding out effect will be small. More generally, Figure 7 shows how the bond supply function traces out the set of outcomes available to the central bank. Setting $\bar{\phi}$ higher implies that banks will hold more bonds in equilibrium, but the liquidity premium will also be larger. By choosing $\bar{\phi}$ appropriately, the central bank can pick out different points on this frontier, but the equilibrium pair (B^*, r_B^*) will always lie on the light blue curve. In this way, choosing the CLF fee allows the central bank to determine either the quantity of bonds held by banks or the equilibrium liquidity premium, but not both.

5.4.2 A fixed-quantity auction facility

Now suppose the central bank chooses to sell a fixed quantity $\overline{F}$ of CLF rights, possibly using an auction format. Figure 8 illustrates the outcome under this approach. For any $\overline{F} < \theta\overline{D}$, Figure 8 shows that there is a unique interest rate r_B such that the difference between the demand for bonds plus CLF rights (the dark blue curve) and the supply of bonds (the light blue curve) is exactly $\overline{F}$. The chosen quantity $\overline{F}$ thus determines the equilibrium interest rate on bonds r_B^* and the equilibrium quantity of bonds B^*. The equilibrium loan rate r_L^* is determined by the point on the red curve corresponding to the total quantity of bonds plus CLF rights, $B^* + \overline{F}$.

Figure 8: Equilibrium with a Fixed-quantity CLF



Comparing Figures 7 and 8, it is clear that the central bank in our model can achieve the same equilibrium outcome using either a fixed-price or a fixed-quantity CLF. In fact, this same outcome will obtain under *any* CLF pricing function ϕ that satisfies:

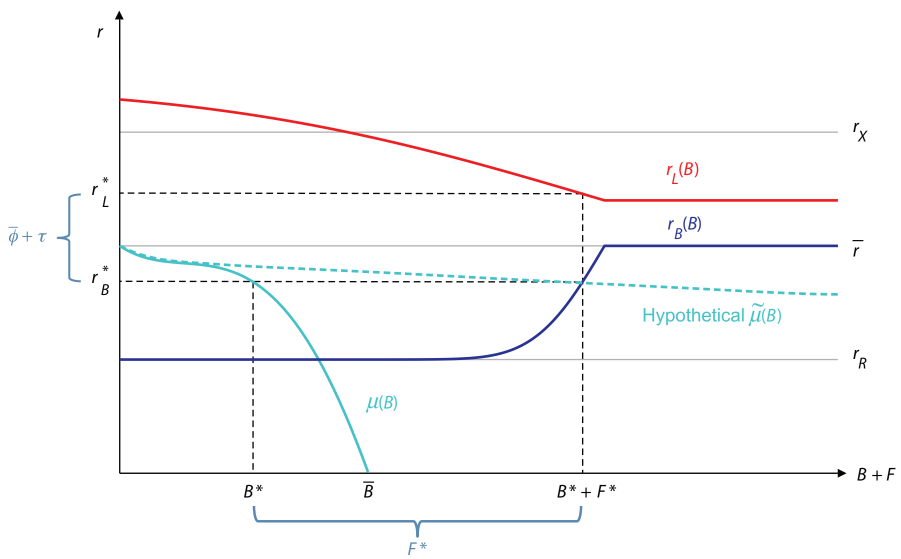
$$\overline{\phi} = \phi\left(\overline{F}\right).$$

In reality, uncertainty about the positions of the (light blue) supply curve and the (dark blue) demand curve are likely to play an important role in determining the best design for the CLF. For example, the fixed-price design is likely to be appealing to a central bank that wishes to stabilise the interest rate spread $r_L^* - r_B^*$ and let the quantity of CLF usage vary depending on financial conditions. The fixed-quantity design, in contrast, would be attractive to a central bank that prefers to keep CLF usage predictable and allow interest rates to change in response to market conditions.

6. Pricing Committed Liquidity

Suppose a central bank has decided to create a CLF, which for ease of exposition we assume to be operated as a fixed-price standing facility. How should the price $\bar{\phi}$ be set? One possibility is to aim to replicate the equilibrium spread $r_L^* - r_B^*$ that would arise in an economy where HQLA is plentiful and there is no CLF. In the context of our model, this requires constructing a hypothetical supply function $\tilde{\mu}(B)$ that would apply if bonds were plentiful in this economy. This function is represented by the dashed light blue curve in Figure 9. The intersection of this hypothetical supply function with the actual demand curve in dark blue determines the interest rates (r_L^*, r_B^*) that would prevail in the hypothetical situation. The central bank would then substitute these interest rates into Equation (31) and set $\bar{\phi}$ accordingly. As shown in Figure 9, the actual bond supply function (in solid light blue) then determines the quantity of bonds held by banks, B^*, and the quantity of CLF rights purchased, F^*. One possible rationale for using this approach is that it equalises the effect of liquidity regulation on interest rates across jurisdictions, even when bond market conditions are very different.

Figure 9: Setting $\bar{\phi}$ Based on a Hypothetical Bond Supply Function

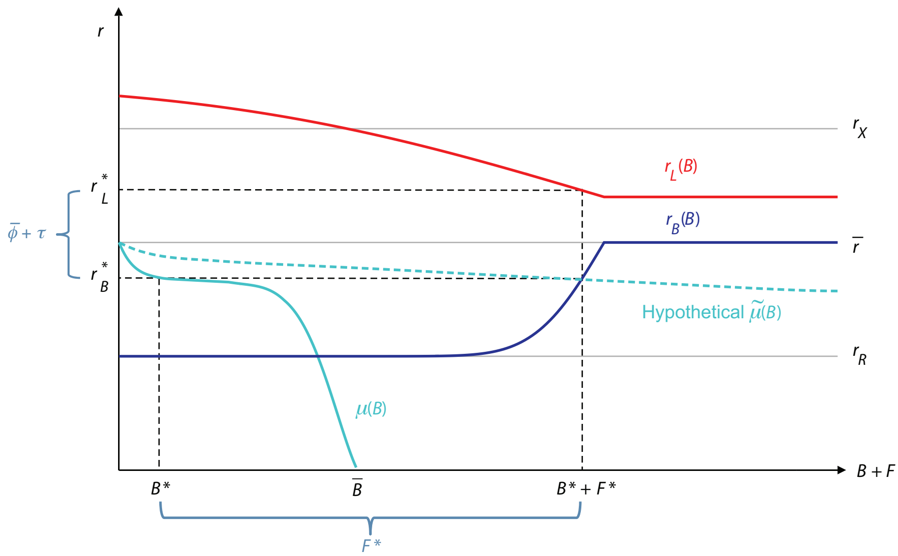


Notice, however, that the equilibrium allocations under the hypothetical supply curve $\tilde{\mu}$ and the actual supply curve μ are far from equivalent. In particular, banks' actual bond holdings B^* are much lower than they would be in the hypothetical situation, even though interest rates are the same. To the extent that one goal of liquidity regulation is to ensure that banks hold a more liquid portfolio of assets, it may be desirable to set the CLF price higher than indicated in Figure 9, which would lead banks to hold more bonds while increasing the interest rate spread $r_L^* - r_B^*$.

In general, the optimal pricing of the CLF is likely to depend critically on the shape of the bond supply function μ, which traces out the trade-off the central bank faces between two competing goals: encouraging banks to hold more bonds, and maintaining spreads at reasonable levels.

Figure 10 makes this point by assuming a very particular shape for the function μ. If the central bank were to follow the procedure described above of pricing the CLF according to the hypothetical supply function $\tilde{\mu}$, the resulting equilibrium would have banks holding a small quantity of bonds and meeting their LCR requirements almost entirely through the purchase of CLF rights. However, the true bond supply function μ is such that if the central bank were to increase $\bar{\phi}$ slightly, banks' bond holdings would rise substantially and reliance on the CLF would diminish. In such a situation, it seems likely that policymakers would prefer the latter outcome, where the spread between r_L^* and r_B^* is slightly wider but banks hold a substantially higher quantity of bonds.

Figure 10: The Importance of the Bond Supply Function for CLF Pricing



While the example in Figure 10 is in some ways extreme, it serves to make the general point that the optimal CLF pricing policy is likely to depend on the bond market conditions within each jurisdiction. In particular, policymakers will need to balance the costs associated with higher spreads against the benefits of having more liquid assets in the banking system. Doing so requires knowledge of how equilibrium interest rates and quantities respond to changes in the CLF pricing structure – that is, knowledge of the bond supply function μ. Estimating this relationship precisely is a difficult task, both *ex ante* and *ex post*. In light of this uncertainty, the RBA and SARB have taken pragmatic approaches in setting their CLF fees and both jurisdictions place a cap on the amount of CLF rights available to a bank (see Table 1). Moreover, the reasoning laid out here suggests that it may be desirable to take a flexible approach to CLF pricing, possibly adjusting terms as more experience is gained with this new policy tool.

7. Conclusion

We have presented a stylised model that can be used to analyse the economic effects of liquidity regulation in the form of an LCR requirement and a CLF. We have shown how the LCR requirement can have significant side effects in a jurisdiction with a limited supply of HQLA, leading to a large regulatory liquidity premium and pushing the short-term interest rate to the floor of the central bank's rate corridor. Introducing a CLF allows the central bank to mitigate these effects, regardless of whether it is organised as a fixed-price standing facility or using a fixed-quantity auction format. By pricing the CLF appropriately, the central bank can control either the equilibrium liquidity premium or the quantity of bonds held by banks, but not both. We argue that the optimal pricing arrangement will need to balance the costs of higher interest rate spreads against the benefits of having more liquid assets in the banking system. Our analysis has shown how the appropriate balance is likely to depend on local bond market conditions and thus may vary across jurisdictions. Moreover, the uncertainty about equilibrium relationships in the new regulatory environment means that central banks are likely to take a flexible approach to CLF pricing, adjusting terms over time as experience with these facilities increases.

While CLFs may not be immediately necessary in jurisdictions outside of Australia, South Africa, and a few others, it is possible they will prove to be a useful policy tool in other situations as well. Stein (2013) argues that a CLF may be beneficial even in jurisdictions where HQLA are plentiful because it allows the central bank to place an upper bound on the costs of liquidity regulation. In addition, as shown in our analysis above, the CLF allows regulation to focus more directly on prices whereas the LCR requirement is focused on quantities. Another possibility is that a CLF could be used as part of a central bank's regular procedures for implementing monetary policy and providing liquidity to the banking system. The Winters (2012) review of the Bank of England's operational framework, for example, suggests that selling CLF rights for an up-front fee, followed by a lower-than-usual interest rate on amounts drawn down, could potentially reduce stigma and other non-price barriers that limited the usefulness of existing facilities during the crisis. The model we present here could potentially be extended to address these issues, which represent an interesting area for future research.

References

BCBS (Basel Committee on Banking Supervision) (2013), *Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools*, Bank for International Settlements, Basel.

Bech ML and T Keister (2013), 'Liquidity Regulation and the Implementation of Monetary Policy', BIS Working Papers No 432.

Davis K (2011), 'Basel III Liquidity Options', Australian Centre for Financial Studies, Financial Regulation Discussion Paper Series 2011-02.

Debelle G (2011), 'The Committed Liquidity Facility', Address to the Australian Prudential Regulation Authority (APRA) and Financial Services Institute of Australia (FINSIA) Basel III Implementation Workshop, Sydney, 23 November.

Debelle G (2013), 'The Impact of Payments System and Prudential Reforms on the RBA's Provision of Liquidity', Address to the Australian Financial Markets Association (AFMA) and Reserve Bank of Australia (RBA) Briefing, Sydney, 16 August.

Goodfriend M (2002), 'Interest on Reserves and Monetary Policy', Federal Reserve Bank of New York *Economic Policy Review*, 8(1), pp 77–84.

Heath A and MJ Manning (2012), 'Financial Regulation and Australian Dollar Liquid Assets', RBA *Bulletin*, September, pp 43–52.

Keister T, A Martin and J McAndrews (2008), 'Divorcing Money from Monetary Policy', Federal Reserve Bank of New York *Economic Policy Review*, 14(2), pp 41–56.

Poole W (1968), 'Commercial Bank Reserve Management in a Stochastic Model: Implications for Monetary Policy', *The Journal of Finance*, 23(5), pp 769–791.

RBA (Reserve Bank of Australia) (2013), 'Liquidity Facilities', Technical Note for Domestic Market Operations, viewed 19 July 2013. Available at <http://www.rba.gov.au/mkt-operations/resources/tech-notes/liquidity-facilities.html>.

South African Reserve Bank (2012), 'Provision of a Committed Liquidity Facility and Utilisation of Statutory Cash Reserves in Terms of the Basel III Liquidity Framework', Guidance Note 5/2012.

Stein JC (2013), 'Liquidity Regulation and Central Banking', Closing Keynote to the Seventh Annual Credit Markets Symposium 'Finding the Right Balance', hosted by the Federal Reserve Bank of Richmond, Charlotte, 19 April.

Whitesell W (2006), 'Interest Rate Corridors and Reserves,' *Journal of Monetary Economics*, 53(6), pp 1177–1195.

Winters B (2012), 'Review of the Bank of England's Framework for Providing Liquidity to the Banking System', presented to the Court of the Bank of England. Available at <http://www.bankofengland.co.uk/publications/Documents/news/2012/cr2winters.pdf>.

Discussion

1. Arthur Yuen

The paper by Morten Bech and Todd Keister provides a very useful framework for considering how a committed liquidity facility (CLF) would operate in practice. For the Liquidity Coverage Ratio (LCR) framework, the CLF is one of the Alternative Liquidity Approaches (ALA) offered to those jurisdictions that have an insufficient supply of high-quality liquid assets (HQLA). To ensure that banks using such facilities are not better off (but not to the extent of being penalised) than banks that do not, the latest LCR text (BCBS 2013, paragraph 58) offers policy guidance on how the CLF commitment fee should be set with reference to relative yields between HQLA and non-HQLA. Specifically, the rules state that the fee should be set to ensure that the net yield on CLF funds is not higher than the net yield on HQLA, or otherwise banks would have an incentive to use the CLF even when not needed. The theoretical model used in this paper for analysing the pricing dynamics of a CLF is, in terms of both its structure and the conclusions, consistent with the policy rationale (which is largely driven by regulatory considerations) behind the LCR rules. Thus, it seems to suggest that the text of the LCR rules is workable in practice.

The paper also applies this analysis of market dynamics to discuss whether the CLF concept could be more widely adopted by central banks in non-ALA jurisdictions as a policy tool for their monetary operations. Presently, under Basel III rules, a CLF is permitted only for jurisdictions with a limited supply of HQLA. There is increasing evidence that LCRs may affect central bank monetary policy. Therefore, other jurisdictions may consider recognising CLFs to meet the LCR so as to prevent the monetary policy transmission mechanism from being constrained.

CLF pricing

The factors considered in this paper are relevant to setting the price of a CLF, and I generally agree with the broad conceptual framework in the paper and its observations. Nevertheless, coming from a central banking authority which is also responsible for banking supervision, I wish to highlight some issues that one should bear in mind when considering this subject. In particular, in setting CLF pricing, we need to be clear about the policy objectives to be achieved. In this regard, central banks and regulators may consider this issue from different perspectives.

The paper sets out an elaborate model that pulls together a number of factors and variables that are relevant to banks' decisions on how much HQLA versus non-HQLA should be held, and whether, and to what extent, they would use the CLF. The model views these decisions as being largely driven by banks' profit-maximisation objectives within the constraint of the LCR requirement. Key considerations are thus the relative yields on HQLA (eligible bonds and central bank reserves) and non-HQLA (loans), and the supply and demand for these assets. However, in a more complex situation with signalling constraints, banks choosing whether to apply for a CLF could also incorporate the potential impact on their reputation, with stigma potentially associated with using a CLF. From the viewpoint of Hong Kong banks, a CLF would not be problematic in positive states of the world, but banks are concerned that during stress periods the market may look on CLF holders with a bias. Ultimately, these non-price factors could substantially affect whether firms use CLFs and the degree to which they use them.

In considering optimal pricing of the CLF, it is also important to be clear about the policy objective in mind. Commercial banks, central banks and regulators may each have a different view of the appropriate price of a CLF. For regulators, conservative pricing of the CLF may be preferred so as not to defeat the purpose of the LCR as a tool to ensure banks self-insure against liquidity risk. That is, pricing should discourage commercial banks from relying on central banks for day-to-day liquidity management (a lender of 'first', rather than 'last' resort). By comparison, for central banks there will generally be a desire to ensure that LCRs do not unnecessarily constrain the control of interest rates and monetary policy transmission. Higher pricing of the CLF would discourage banks from using a CLF when not strictly necessary, but would defeat the purpose of the CLF if prices were so high that no firm chose to use it.

Operation of the CLF under the LCR

Another important observation of the paper is related to what policymakers may consider when operationalising the CLF under the LCR. The paper suggests that the fee set on the CLF always equalises the yield spread between HQLA and non-HQLA assets. The market dynamics for this result are not difficult to understand: as long as the fee is less than the price premium on HQLA, commercial banks will substitute into the CLF; the demand for HQLA will consequently fall, reducing the yield spread until it equals the cost of the CLF. While this is how the market dynamics should work, paragraph 58 of the LCR rules states that a central bank should price the CLF to preclude any net yield advantage from using the CLF (see BCBS (2013)). From my interpretation, this is an *ex ante* requirement. Assuming market dynamics ultimately bring the yield spread between HQLA and non-HQLA back to the CLF pricing level in practice, we need to be very careful to oppose any argument that the specific LCR policy objectives outlined in paragraph 58 are met simply by CLF pricing ultimately being equal to the yield spread on an *ex post* basis.

In jurisdictions where the supply of HQLA is not an issue, the yield spread between HQLA and non-HQLA is equally relevant. Moreover, the stigma associated with using the CLF may be more prominent. A commercial bank relying habitually upon these facilities for meeting liquidity requirements sends a particularly negative signal when it is known that there is a sufficient supply of HQLA in the market. The stigma issue could thus become particularly relevant in times of stress, so the design of the CLF would be particularly important in order to avoid this issue. In these non-ALA jurisdictions, there is a strong prudential case to price the CLF in a slightly more penal manner in order to reduce its attractiveness. The incentive for commercial banks to use CLFs strategically in a non-ALA environment is much higher than in an ALA environment; hence more caution is needed in pricing.

Regulatory issues and challenges

There are other regulatory issues and challenges that affect the operation of a CLF under the LCR. For example:

- Designing the terms and structure of a CLF appropriately to guard against moral hazard and address stigma issues.
- The need for regulatory constraints on a CLF, for example collateral policy and scope of recognition under the LCR, rather than pricing only.
- The extent of international harmonisation of the CLF structure, noting that full standardisation is impractical but divergence in policy will create level playing field issues.
- Operating a CLF differently in normal and stressed states, which further requires clearly defining such periods.
- The effect of a CLF on the operation of other central bank facilities such as emergency liquidity facilities.

This model structure will provide a good starting point for understanding the pricing issue, but the factors above may be equally if not more important decisions for the central bank, especially in a non-ALA environment. It is also important to conduct further studies on whether there are other factors to include in the analysis.

Reference

BCBS (Basel Committee on Banking Supervision) (2013), *Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools*, Bank for International Settlements, Basel.

2. General Discussion

The paper by Morten Bech and Todd Keister, and Arthur Yuen's discussion, were both the subject of robust discussion. Central to the discussion were a range of questions exploring how the analysis would be affected by incorporating various additional features into the model. One participant asked how the analysis would change under an interest-on-reserves monetary policy framework, where there was no shortage of reserves to meet the LCR. Dr Keister indicated his personal support for such a system if the central bank could supply reserves by purchasing government bonds, noting that in jurisdictions such as Australia the shortage of HQLA would still bind. A second participant noted that the penalty for breaking the LCR was exogenous in the model, and asked whether this could be treated as another policy instrument. Dr Keister clarified that in the current model the penalty came from the fact that banks were forced to borrow at the discount window to meet the LCR, but that penalty could be separately identified in a more detailed model.

Another participant suggested that in practice banks would prefer to hold bonds rather than reserves to meet a HQLA requirement, because bonds could be used for other purposes, including repo. They also noted that bonds generally attracted a premium, and asked if they would attract a higher yield than reserves in the model's equilibrium. Dr Keister responded that, given the quantity of reserves was set by the central bank, prices would adjust so that banks were indifferent at the margin between holding bonds and reserves. He also agreed that the bond yield would be higher in equilibrium, but noted that the spread would be negligible when banks rely on the central bank to create a large volume of reserves to meet their LCR requirements. Dr Bech concurred, and noted that there would be differences in spreads between bond yields but that this would not affect the core analysis.

Another discussion was motivated by the comment that CLFs were not designed to be used as an economic choice for banks. One participant noted that the Australian implementation of the CLF involved a prudential supervisor deciding the amount of CLF funding allocated to banks. Dr Keister responded that in their model, banks made an economic choice to use the cheaper of the CLF and bonds such that marginal costs were equalised, and stated that he did not think the regulations were definitive on this matter. The participant further suggested that the price of the CLF was irrelevant in a jurisdiction with a shortage of HQLA, because a CLF was then only used by banks under compulsion. Dr Keister disagreed about the relevance of pricing, stating that, at the margin, more bonds could move into the banking system, and that CLF pricing could affect other market interest rates in equilibrium, even if quantity movements from substitution were small.

The potential for stigma concerns to reduce the use and thus the efficacy of CLFs was explored by several participants. Responding to Mr Yuen's discussion, Dr Keister agreed that stigma was an important factor not considered in the model, but suggested that the scope for stigma could be mitigated by an appropriately designed auction mechanism. He hypothesised that by auctioning a fixed quantity of CLF, the equilibrium result could not be characterised by all parties staying away due to stigma concerns.

The potential for stigma was also considered in a discussion about the appropriate pricing of the CLF. Several participants summarised the CLF as an insurance mechanism for a liquidity crisis, and asked whether its price in the model incorporated the expected cost of the adverse outcome, or varied in accordance with counterparty risk. One participant then noted that invariant pricing could create a substantial adverse selection problem in economies that were not HQLA-constrained and, as a result, accessing the CLF would send a strong negative signal about the bank's solvency. Separately, Dr Keister responded to a question about how to resolve a situation in which multiple regulators had different views of appropriate pricing, saying that parties would need to agree on a desired equilibrium, and then use the CLF to bring it about.

In response to several queries about competition in the provision of liquidity insurance between central banks and, where relevant, the private sector through collateral swaps and rehypothecation, Mr Yuen clarified his previous comments about level playing field issues with the CLF. He stated that without international harmonisation of what collateral was acceptable for CLF purposes, a bank operating in multiple jurisdictions could arrange its operations to take advantage of less stringent rules. He suggested that other differences could also give rise to similarly unearned competitive advantages.

The discussion concluded with a debate over why policymakers would prefer banks to manage their own liquidity arrangements, rather than have central banks supply liquidity against illiquid assets. Several participants suggested that reliance on central bank liquidity reduced the incentives for banks to undertake thorough risk management. In particular, it was pointed out that permanently moving bank assets to the central bank's balance sheet would involve the central bank taking on substantial credit risk and potential losses. Rather, central banks were more comfortable providing liquidity on a contingent basis, where a bank's solvency could be assessed before choosing whether to provide loan funding.

Funding Flows and Credit in Carry Trade Economies

Silvia Miranda Agrippino and Hélène Rey*

1. Introduction

A carry trade is a transaction where an investor borrows at a low interest rate in one country and invests in assets that have a higher (risk-adjusted) yield in another. For countries that are carry trade targets due to their relatively high risk-adjusted rates of return, life oscillates between 'paddling in an ocean of global money' (Sighvatsson 2007) and being stranded by the receding tide on bumpy shores. Despite the importance of carry trade flows for the macroeconomic outcomes of these countries, most of the literature on the carry trade focuses on the price dimension.

Galati, Heath and McGuire (2007) provide a detailed discussion of multiple carry trade strategies and of the likely extent of carry flows for a number of countries, while Burnside *et al* (2011) and Jorda and Taylor (2012), among others, have analysed the profitability of different carry trade strategies.

Carry trade profits and risk-adjusted returns (Sharpe ratios) are living proof that uncovered interest parity (UIP), at least in the short to medium run, is a convenient textbook shortcut that is grossly falsified by reality. Deviations from UIP and the forward premium puzzle have led to a massive literature in international finance (see, for example, Frankel (1983) and Fama (1984)). Brunnermeier, Nagel and Pedersen (2008) reconcile UIP and the carry trade phenomenon by showing that carry traders are exposed to liquidity risk and that occasional sharp reversals may wipe out the carry element of the excess return. Similarly, Farhi and Gabaix (2011) argue that currency investors are subject to country-specific, time-varying rare disasters.

Gagnon and Chaboud (2007) emphasise the massive exchange rate effects of a carry trade unwinding. Lustig and Verdelhan (2007) and Lustig, Roussanov and Verdelhan (2010) suggest that foreign currencies must pay high excess returns as they tend to depreciate against the US dollar precisely when US consumption growth is low. Abhyankar, Gonzalez and Klinkowska (2012) show that a conditional consumption capital asset pricing model (CAPM) is able to price a large variation in the cross-section of carry trade portfolios. Bacchetta and van Wincoop (2010) invoke infrequent portfolio decisions to explain the slow exchange rate appreciation and rapid reversal pattern associated with carry trade episodes.

Instead of focusing on the failure of UIP and the profitability of the carry trade, in this paper we present an empirical study of the effects that capital flows (the funding flows) have on asset prices, the provision of credit and the stance of monetary policy in the target countries. In this we relate

* London Business School. Hélène Rey is also affiliated with the National Bureau of Economic Research (Cambridge), and the Centre for Economic Policy Research (London). Rey is grateful to the ERC for financial support (grant number 210584).

to two recent theoretical papers: Plantin and Shin (2011) who emphasise funding externalities and strategic complementarities among speculators as well as the role of monetary policy rules in sustaining the carry trade flows and Truempler (2013) who studies the interactions between carry trade flows, monetary policy and the real economy in a quantitative model of a small open economy. In Section 2 of the paper we describe the pattern of cross-border credit flows; we analyse their determinants in Section 3. Section 4 discusses the existence of co-movement in asset prices and in particular house prices. We study interactions between credit flows, the VIX and monetary policy in Section 5, before concluding in Section 6.

2. 'An Ocean of Global Money': The Pattern of International Flows

Our sample of carry trade target countries includes: Australia, Brazil, Canada, Hungary, Iceland, Israel, Mexico, New Zealand, Norway, Poland, South Africa, South Korea, Sweden and Turkey. All these economies have been the recipients of massive capital flows in the past decade and their financial sectors have experienced large increases in the availability of liquidity; moreover, most of these countries have been included in previous studies on the carry trade. These countries are all small to medium-sized open economies with floating exchange rates, according to the International Monetary Fund (IMF) *Annual Report on Exchange Arrangements and Exchange Restrictions* (IMF 2012). Some of them are 'free floaters' (Australia, Canada, Mexico, New Zealand, Norway, Poland and Sweden), while the remainder manage their exchange rates to some degree, but are still classified as 'floaters'. They are mostly financially open, though some of them have erected barriers to capital flows, especially in recent years. For example, the tax imposed by Brazil on some capital inflows in 2009 and the crisis restrictions of Iceland on capital outflows since 2008.

It has been noted in the literature that cross-border capital inflows exhibit strong co-movements across countries and are volatile. For example, Calvo, Leiderman and Reinhart (1996) note that 'global factors affecting foreign investment tend to have an important cyclical component, which has given rise to repeated booms and busts in capital inflows'. Among these factors, Reinhart and Reinhart (2009) have identified world real rates, world growth rates and commodity prices as important drivers of capital flow 'bonanzas'. In this paper, we will focus on cross-border credit flows, a subcategory of capital flows, as their importance has grown with the development of global banking after the 1990s and they tend to be particularly procyclical with rapid build-ups in good times and sharp reversals in crisis times (see CIEPR (2012)).

Figure 1 shows the outstanding end-of-quarter amount of direct cross-border credit available to the countries in our panel from 1990 to the end of 2012. We define direct credit as the funding available through direct borrowing from non-resident banks (loans and securities) to both banks and non-banks of the recipient country (see Appendix A for more details on the data). Avdjiev, McCauley and McGuire (2012) emphasise the importance of cross-border credit flows in igniting credit booms in emerging markets.

Figure 1: Total Direct Cross-border Credit
(*continued next page*)

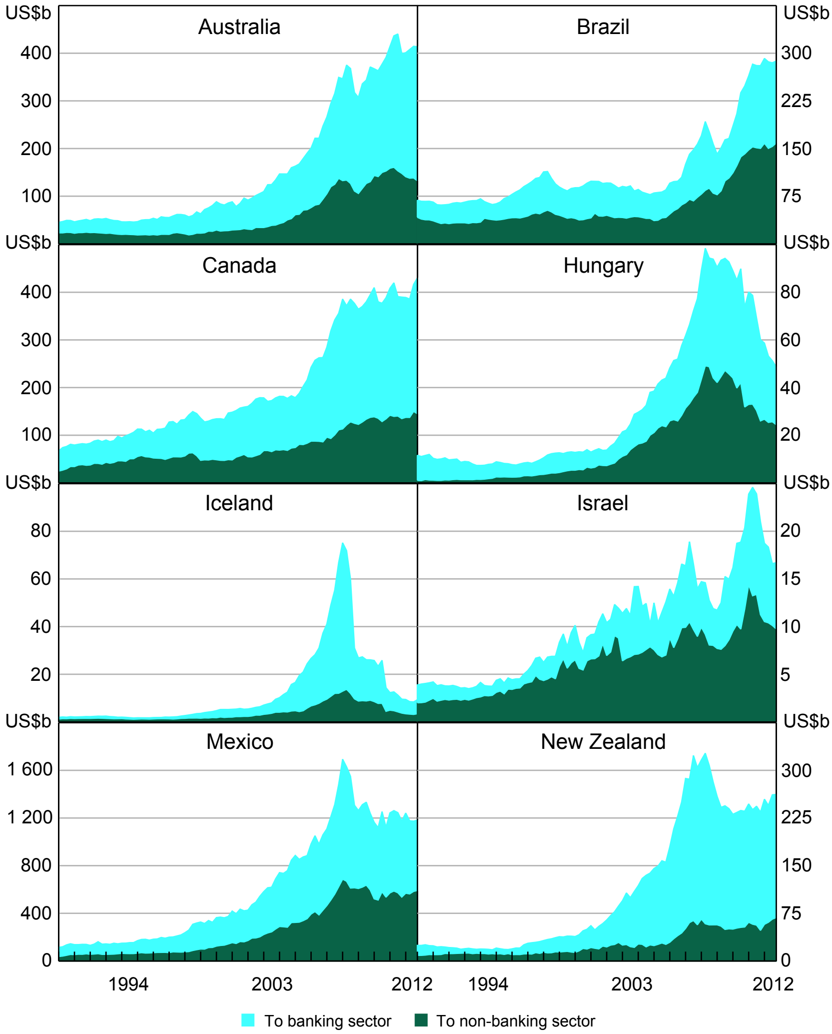
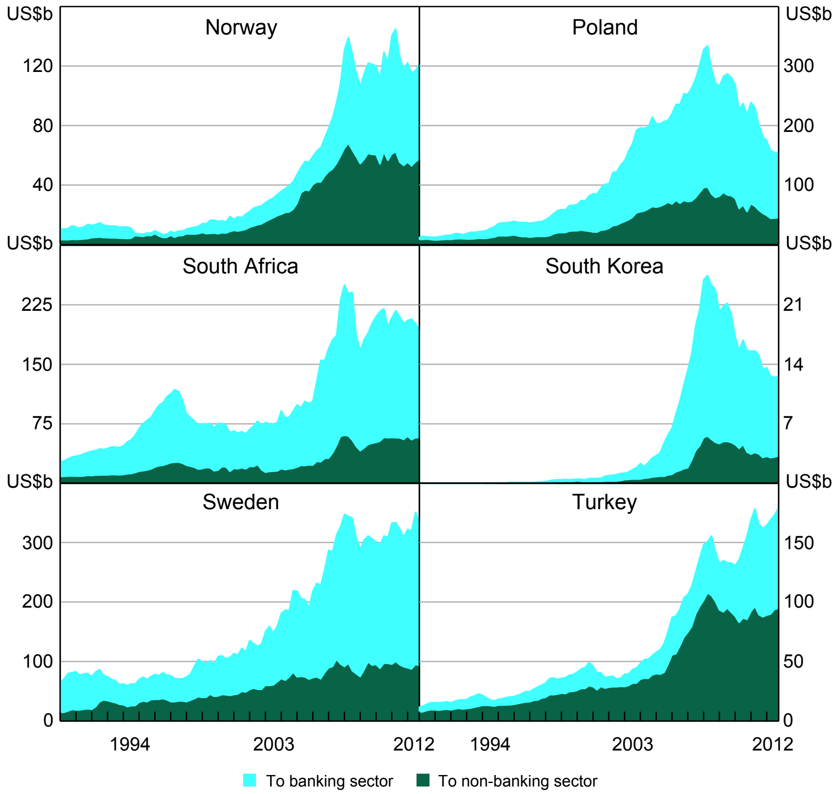


Figure 1: Total Direct Cross-border Credit
(*continued*)



Notes: Claims on all sectors of non-residential banks; all instruments, all currencies
Source: BIS locational banking statistics

We see a strikingly common pattern for credit inflows across most of these economies: inflows were relatively stable between 1990 and 2000 (with noticeable differences in scales depending on the size of the countries) while there was a sharp increase in the size of inflows around 2000 for most of the economies; this is especially true for Australia, Canada, Hungary, Iceland, Israel, Mexico, Poland and Sweden. Flows into Norway, South Korea and Turkey picked up (spectacularly) a little later. For some of the countries (Australia, Canada, Iceland, New Zealand, Poland, South Korea and Sweden) the share of credit inflows intermediated by the banking sector increases massively in the years preceding the financial crisis and remains a significant portion of outstanding credit from non-resident banks.

There is a high degree of synchronisation of cross-border credit flows in our sample of small open economies, irrespective of the continent, the income level and the details of the exchange rate regime.

3. Determinants of Credit Inflows

The role of global banks in the world economy and their financing patterns has been the subject of much interest recently (see, for example, Borio and Disyatat (2011); Cetorelli and Goldberg (2012)). Bruno and Shin (2013a) build a model of international banking flows in which global banks finance themselves in the US dollar markets and channel liquidity to all other regions of the world via the local banking systems. They use a variant of the Vasicek (2002) model with a two-tier banking system. In their framework, the level and the growth rate of bank leverage are important determinants of capital flows on the supply side. They show empirically that the leverage of banks is strongly negatively related to the VIX,[1] which is widely seen as a market proxy for risk aversion and uncertainty. One possible rationale for this correlation is that, in a system where value at risk is both a regulatory tool and a metric used internally by banks to measure risk, there is a lot of credit creation when measured risks are low. This credit creation in turn pushes up asset prices, compresses spreads and renders measured risks even lower, eventually leading to more leverage. Hence, when the VIX is low, global banks leverage a lot by financing themselves in the US dollar markets, and channel vast amounts of liquidity to other regions of the world, where they lend to local banks. This process ultimately leads to an increase in the leverage of local banks which tend to borrow more in tranquil times.

On the demand side, the Bruno and Shin (2013a) model suggests that increases in equity capital of local banks and lower local stock market volatility are important determinants of larger cross-border inflows. Cross-border lending should also be increasing in the interest rate spread between the local lending rate and the interest rate of the funding currency. The authors find support for their predictions in a panel of 46 countries and show that supply-side factors tend to dominate demand-side factors as drivers of credit flows. In their study, a lower VIX (in level and growth rate) is associated with increases in cross-border credit flows. This confirms earlier results of the literature, for example studies by Brunnermeier *et al* (2008) and Forbes and Warnock (2012) that emphasise the strong co-movements of capital flows with the VIX.

In Tables 1 to 3 we study the determinants of cross-border credit inflows. We build on the specification of Bruno and Shin (2013a) and run a set of panel regressions involving data for the 14 countries in our sample. The panel is not balanced due to different, and sometimes limited, availability of data.

We use a fixed set of regressors in all our estimations which consists of the lagged log of the VIX; the current quarterly VIX growth rate; lagged local equity market volatility (Vol); and current local bank equity capital growth (Eqy). These variables are meant to capture global and local determinants. We control for other local variables such as the real exchange rate (RER), GDP growth, the growth in the debt-to-GDP ratio, M2 growth, inflation (Π) and the change in the spread between the local policy rate and the US federal funds rate. The majority of data series are available from 1990:Q1 to 2012:Q4. All data are at quarterly frequency except local stock market volatility and local bank equity capital growth (proxied by return on assets) which are annual. Flows are expressed in log differences. All controls are lagged. Standard errors are adjusted for clustering at the country level.

1 The VIX is the Chicago Board Options Exchange Market Volatility Index. It is a measure of the implied volatility of S&P 500 index options.

Table 1 investigates the ability of these variables to predict direct cross-border credit inflows to all sectors, while Tables 2 and 3 repeat the same analysis focusing on credit to banks and non-banks respectively. We explain up to 42 per cent of the variation in direct credit inflows. Coefficients enter with the expected signs. Direct credit inflows are strongly negatively related to the VIX, falling when the financial markets uncertainty goes up. They also tend to fall when the growth rate of the VIX goes up but this is not always significant. Similarly, inflows tend to fall when the volatility of the local equity market goes up (though this effect is not significant). Flows increase strongly when local equity goes up. They also increase when the growth rate of M2 goes up in the target country. Flows increase with the interest rate differential though this effect is not significant. Changing the controls does not alter the results.

Table 1: Direct Credit Flows to All Sectors

Fixed effect estimator over full sample

	(1)	(2)	(3)	(4)	(5)	(6)
VIX_{t-1}	–0.0366***		–0.0802***	–0.0427***		–0.0824***
	(–3.05)		(–7.13)	(–3.18)		(–4.53)
ΔVIX_t	–0.0014		–0.0094	–0.0337***		–0.0467
	(–0.21)		(–0.40)	(–2.75)		(–1.28)
Vol_{t-1}		–0.0545	–0.0247		–0.0373	–0.0108
		(–1.38)	(–0.58)		(–0.80)	(–0.21)
ΔEqy_t		0.0059***	0.0054***		0.0044***	0.0048***
		(16.08)	(20.92)		(7.58)	(5.53)
ΔRER_{t-1}				–0.1412***	–0.3272	–0.2167
				(–3.36)	(–1.52)	(–1.12)
ΔGDP_{t-1}				–0.0427**	–0.0788	–0.0858*
				(–2.28)	(–1.47)	(–1.84)
$\Delta(Debt/GDP)_{t-1}$				–0.0059	–0.0052	–0.0001
				(–1.06)	(–0.75)	(–0.01)
$\Delta M2_{t-1}$				0.0749*	0.1583***	0.1583***
				(2.47)	(4.49)	(4.88)
Π_{t-1}				–0.3099*	–0.5973**	–0.0969
				(–1.69)	(–2.05)	(–0.32)
$\Delta(i-i_{US})_{t-1}$				0.0063	0.0064	0.0123
				(1.30)	(0.35)	(0.72)
Linear trend	Yes	Yes	Yes	Yes	Yes	Yes
Adj R^2	0.015	0.310	0.391	0.089	0.385	0.428
Within group R^2	0.017	0.320	0.407	0.102	0.425	0.473
N	1 259	194	194	640	139	139
n	14	14	14	14	14	14

Notes: Standard errors adjusted for clustering at country level; *, ** and *** denote significance at the 10, 5 and 1 per cent levels, respectively; *t*-statistics are in parentheses

Table 2: Direct Credit Flows to Bank Sector
Fixed effect estimator over full sample

	(1)	(2)	(3)	(4)	(5)	(6)
VIX_{t-1}	–0.0271**		–0.0800***	–0.0420***		–0.0690**
	(–2.32)		(–6.55)	(–2.80)		(–2.48)
ΔVIX_t	0.0124		–0.0005	–0.0335**		–0.0484
	(1.03)		(–0.02)	(–2.07)		(–1.10)
Vol_{t-1}		–0.0403	–0.0093		–0.008	0.0124
		(–0.90)	(–0.20)		(–0.16)	(0.24)
ΔEqy_t		0.0074***	0.0069***		0.0046***	0.0048***
		(15.02)	(17.91)		(4.30)	(3.04)
ΔRER_{t-1}				–0.1608**	–0.3191	–0.2376
				(–2.69)	(–1.21)	(–0.97)
ΔGDP_{t-1}				–0.0246	–0.0929	–0.0973
				(–1.02)	(–1.27)	(–1.54)
$\Delta(Debt/GDP)_{t-1}$				–0.0056	–0.0218	–0.0181
				(–0.81)	(–1.40)	(–0.89)
$\Delta M2_{t-1}$				0.0873**	0.1943***	0.1959***
				(2.21)	(3.66)	(3.46)
π_{t-1}				–0.2138	–0.2804	0.1503
				(–0.75)	(–0.58)	(0.33)
$\Delta(i-i_{US})_{t-1}$				0.0045	–0.0023	0.0026
				(0.72)	(–0.09)	(0.10)
Linear trend	Yes	Yes	Yes	Yes	Yes	Yes
Adj R^2	0.002	0.241	0.287	0.049	0.321	0.331
Within group R^2	0.004	0.253	0.306	0.062	0.365	0.384
N	1 258	194	194	640	139	139
n	14	14	14	14	14	14

Notes: Standard errors adjusted for clustering at country level; *, ** and *** denote significance at the 10, 5 and 1 per cent levels, respectively; *t*-statistics are in parentheses

Table 3: Direct Credit Flows to Non-bank Sector

Fixed effect estimator over full sample

	(1)	(2)	(3)	(4)	(5)	(6)
VIX_{t-1}	–0.0371***		–0.0765***	–0.0404***		–0.0880***
	(–3.26)		(–4.54)	(–3.14)		(–3.60)
ΔVIX_t	–0.0122		–0.0208	–0.0335***		–0.0523
	(–1.54)		(–0.65)	(–3.59)		(–1.14)
Vol_{t-1}		–0.0791**	–0.0525		–0.0792*	–0.0513
		(–2.21)	(–1.35)		(–1.68)	(–0.96)
ΔEqy_t		0.0017***	0.0012***		0.0009**	0.0012**
		(5.40)	(5.06)		(2.07)	(2.12)
ΔRER_{t-1}				–0.0991*	–0.3289	–0.2138
				(–2.62)	(–1.69)	(–1.24)
ΔGDP_{t-1}				–0.0449*	–0.0327	–0.0399
				(–1.86)	(–0.64)	(–0.79)
$\Delta(Debt/GDP)_{t-1}$				–0.0041	0.005	0.0103
				(–1.60)	(0.95)	(1.37)
$\Delta M2_{t-1}$				0.0185	0.0659	0.0662
				(0.64)	(1.17)	(1.26)
π_{t-1}				–0.4973**	–0.9375**	–0.3999
				(–2.44)	(–2.13)	(–1.04)
$\Delta(i - i_{US})_{t-1}$				0.0099*	0.018	0.0244*
				(2.23)	(1.15)	(1.65)
Linear trend	Yes	Yes	Yes	Yes	Yes	Yes
Adj R^2	0.018	0.151	0.229	0.047	0.152	0.212
Within group R^2	0.020	0.165	0.249	0.060	0.207	0.275
N	1 259	194	194	640	139	139
n	14	14	14	14	14	14

Notes: Standard errors adjusted for clustering at country level; *, ** and *** denote significance at the 10, 5 and 1 per cent levels, respectively; *t*-statistics are in parentheses

The results of Table 2 (credit flows to the banks) and Table 3 (credit flows to the non-banks) are largely similar to the results of Table 1. There are some minor differences – the interest rate spread variables tend to be more significant, and the role of M2 is less significant, while past inflation tends to dampen flows to non-banks. To sum up, we confirm in our panel of carry trade economies that credit flows are procyclical and highly negatively correlated with the VIX. Small open economies, whether floaters or free floaters, like other economies receive capital inflows in a way which is closely related to a 'global financial cycle' reflecting the leverage of financial intermediaries and proxied by the VIX (see Miranda Agrippino and Rey (2012) and Rey (2013)).

4. Asset Prices and the VIX

Miranda Agrippino and Rey (2012) use a large cross-section of 858 risky asset prices distributed across five continents and show that an important part of the variance of risky returns (25 per cent) is explained by a single global factor. This result is striking as the set of assets used in the estimation is heterogeneous. It contains stocks, corporate bonds and commodities. Risky returns on all continents and across asset classes give weight to the contribution of this global factor. Miranda Agrippino and Rey (2012) show that this global factor is closely related to the VIX. These results, combined with those in the previous section, indicate both cross-border credit flows and risky asset prices are closely related to global fluctuations in uncertainty and risk aversion.

Since real estate prices have proved to be a very important component of financial crises both in emerging markets and in advanced economies, we now investigate whether they also follow a global cycle. To do this, we look at a panel of house prices for our set of countries. All regressions include the lagged log of the VIX; current VIX growth; and credit flows to all sectors (FlwAll), flows to the banking sector (FlwBS) and flows to non-banks (FlwNBS) all expressed as a ratio to GDP and lagged by one quarter. Controls include lagged GDP and M2 growth, the lagged nominal effective exchange rate (NEER), and the lagged change in the spread between the local policy rate and the US federal funds rate. We also test in the cross-section whether the sensitivity of real estate markets to the global factor can be related to different intensities of credit flows into those markets. In order to do so, we augment our regressions with a term that interacts the VIX with measures of credit flows. Results are reported in Table 4.

Table 4: Property Price Indices
Fixed effect estimator over full sample

	(1)	(2)	(3)	(4)	(5)	(6)
VIX_{t-1}	–0.0114**	–0.0114**	–0.0115**	–0.0115**	–0.0115**	–0.0115**
	(–2.12)	(–2.14)	(–2.15)	(–2.15)	(–2.16)	(–2.17)
ΔVIX_{t}	–0.0067**	–0.0067**	–0.0068**	–0.0067**	–0.0067**	–0.0068**
	(–2.46)	(–2.48)	(–2.52)	(–2.47)	(–2.49)	(–2.52)
$FlwALL_{t-1}$	0.0042*					
	(1.67)					
$FlwBS_{t-1}$		0.0043*				
		(1.75)				
$FlwNBS_{t-1}$			0.0154			
			(0.86)			
$FlwALL_{t-1}$ x VIX_{t-1}				0.0011*		
				(1.66)		
$FlwBS_{t-1}$ x VIX_{t-1}					0.0011*	
					(1.67)	
$FlwNBS_{t-1}$ x VIX_{t-1}						0.006
						(1.07)
ΔGDP_{t-1}	0.0566**	0.0570**	0.0636***	0.0564**	0.0570**	0.0624***
	(2.53)	(2.55)	(3.01)	(2.50)	(2.53)	(2.92)
$\Delta M2_{t-1}$	0.0099	0.0097	0.0092	0.0102	0.0099	0.0096
	(0.71)	(0.69)	(0.64)	(0.71)	(0.69)	(0.66)
$\Delta(i - i_{US})_{t-1}$	–0.0016	–0.0016	–0.0016	–0.0016	–0.0016	–0.0016
	(–1.18)	(–1.18)	(–1.24)	(–1.17)	(–1.18)	(–1.22)
$NEER_{t-1}$	0.0237*	0.0242*	0.0245*	0.0241*	0.0246*	0.024*
	(1.66)	(1.73)	(1.66)	(1.70)	(1.76)	(1.64)
Linear trend	Yes	Yes	Yes	Yes	Yes	Yes
Adj R^2	0.127	0.127	0.124	0.127	0.127	0.125
Within group R^2	0.138	0.138	0.135	0.138	0.138	0.136
N	642	642	643	642	642	643
n	14	14	14	14	14	14

Notes: Standard errors adjusted for clustering at country level; *, ** and *** denote significance at the 10, 5 and 1 per cent levels, respectively; *t*-statistics are in parentheses

We find that property prices are negatively related to the VIX and are also significantly negatively related to its growth rate. We also find that more credit flows tend to be associated with higher property prices (this is true for the aggregate flows to all sectors but particularly for flows to banks). We do not find, however, that the sensitivity of real estate markets to the VIX increases with capital flows. It is worth emphasising that none of the above regressions indicate causality. They merely indicate (striking) correlations between the VIX, property prices and credit flows.

5. Credit Creation, Financing Costs and the Ocean of Money

What creates the ocean of money engulfing the shores of carry trade targets? More prosaically, what are the determinants of the fluctuations in the VIX? Given the strong procyclicality of credit flows and the way global banks operate (see, for example, Shin (2012)) it is natural to investigate the effect on the 'global financial cycle' of refinancing costs in dollars, that is Federal Reserve monetary policy and its effect on credit creation and on credit flows (see also Rajan (2005) for the link between monetary policy and risk taking). As an alternative, it would also be very interesting (but out of the scope of this paper) to study the effect of refinancing costs on the yen market.

Bekaert, Hoerova and Lo Duca (2012), Miranda Agrippino and Rey (2012), and Bruno and Shin (2013b) perform VAR analyses and, under some identification assumptions, suggest that monetary policy in the centre country is one of the determinants of the VIX. When the federal funds rate goes down, the VIX falls, banks' leverage rises, as do gross credit flows. Their estimates suggest that between 10 and 30 per cent of the variance of the VIX is explained by shocks to the federal funds rate in the 1990–2007 period.

What are the dynamic interactions of the VIX with credit and spreads in the specific case of Australia?

We build on the study of Bekaert *et al* (2012). They show that movements in the federal funds rate have an effect on uncertainty (expected stock market volatility) and risk aversion, two components they extract from the VIX. Like them, we focus on the links between monetary policy (defined in our case as the spread of the local policy rate over the federal funds rate) and the VIX but, unlike them, we also study their dynamic interrelations with currency fluctuations, credit flows and growth. We also build on Miranda Agrippino and Rey (2012) in which a detailed analysis of the determinants of the fluctuations of the VIX, jointly with leverage and credit and US monetary policy, is performed. Bruno and Shin (2013b) also perform a related analysis and focus on the delayed overshooting puzzle and movements in the US dollar.

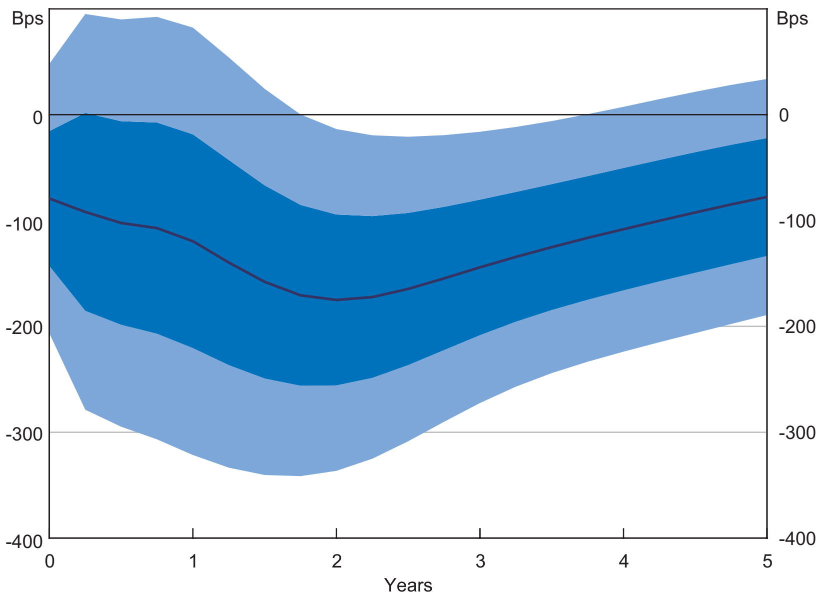
5.1 Monetary policy and credit in a target economy (Australia) and the VIX

To study the interaction between monetary policy, credit flows and the VIX we run a 7 variable recursive VAR on Australian quarterly data from 1990:Q1 to 2012:Q4. The period is constrained by data availability with the VIX starting only in 1990. The variables included in the VAR are, in the following order: real GDP, prices (measured as the log of the implicit GDP price deflator), credit measures (domestic credit and total direct cross-border credit), the interest rate spread between the Australian official cash rate and the US effective federal funds rate (proxy for funding cost), the nominal exchange rate between Australian and US dollars (domestic price of foreign currency so an increase means a depreciation of the Australian dollar) and the VIX. The ordering of the variables in the VAR reflects the assumption that financial variables (the VIX and exchange rate) react quickly (i.e. within the quarter) to shocks to interest rates while it would take at least one quarter for GDP, prices and credit variables to respond. This type of identifying assumption is often used in the monetary policy literature. All variables except the interest rate differential and the exchange rate are logged. The VAR includes two lags of each variable, which was selected using a combination of criteria.[2]

Results in the form of orthogonalised impulse response functions are shown in Figures 2 to 5 below. Shaded areas are 1 (dark) and 2 (light) standard deviation bootstrapped confidence bands obtained with 1 000 replications.

In Figure 2, we show the response of the AUD/USD exchange rate to a 50 basis point increase in the spread of the Australian policy rate over the US federal funds rate. These results are consistent with the dynamics of carry activity: the Australian dollar appreciates against the US dollar following an increase in the spread between the two currencies; the appreciation is both significant and persistent.

Figure 2: Exchange Rate Response to a Change in the Interest Rate Differential



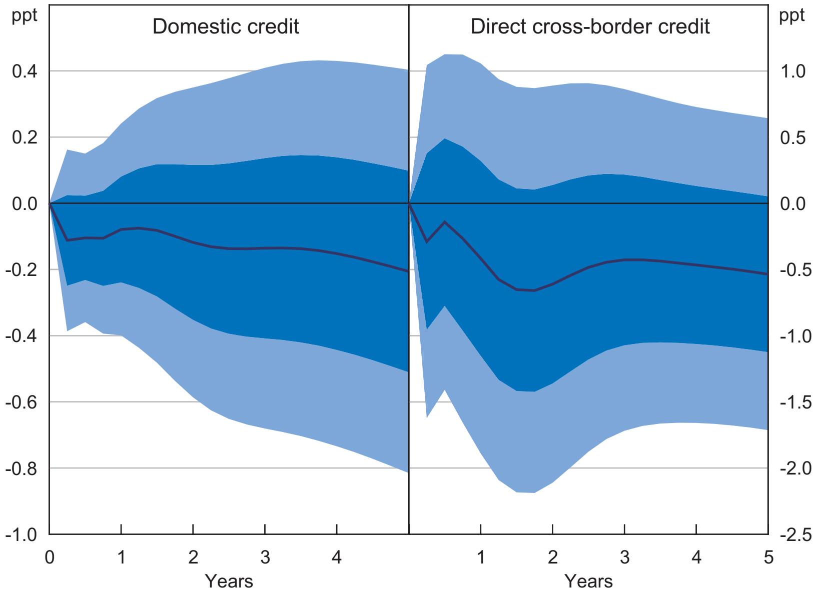
Notes: Response of AUD/USD exchange rate (domestic price of foreign currency) to a 50 basis point increase in the interest rate differential measured as the difference between the Australian official cash rate and the US effective federal funds rate; bootstrapped one and two standard deviation confidence bands are obtained using 1 000 replications

Figures 3, 4 and 5 explore how credit flows and credit creation are influenced by changes in the interest rate spread, the exchange rate and the VIX. Shocks are normalised to a 50 basis point increase in spread and a 1 per cent increase in both the exchange rate and the VIX; responses are in percentage points.

2 It is customary, when using data sampled at quarterly frequency, to include up to four lag in the VAR estimation; here, however, due to limited data availability we choose to rely on likelihood ratio and Bayesian Information Criterion for lag selection to avoid over fitting. We also run a number of smaller VARs where we drop a subset of our seven variables each time to check for the robustness of our results.

Figure 3 shows that an increase in the interest rate differential (the spread of the Australian rate over the US rate) has very little impact on domestic credit or on direct cross-border credit; while both tend to react negatively, the effect is not significant.

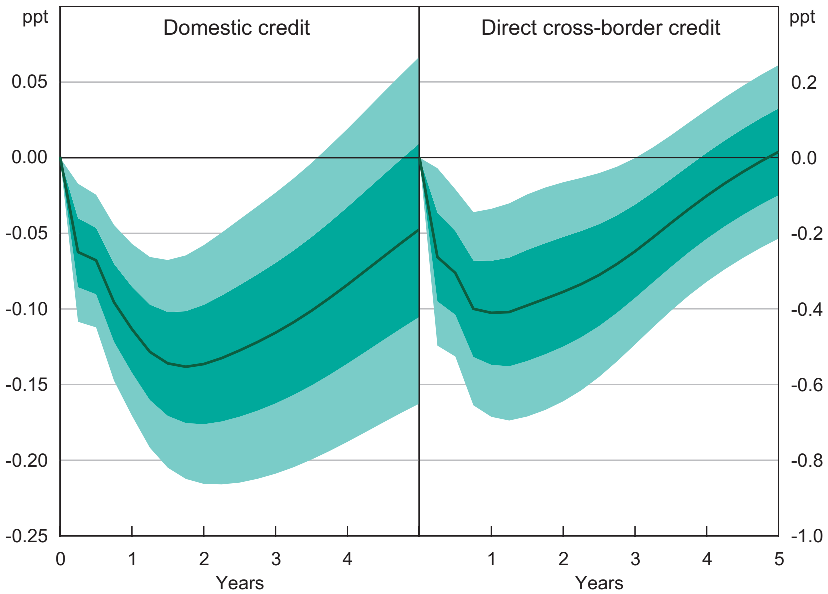
Figure 3: Responses to a Change in the Interest Rate Differential



Notes: Responses to a 50 basis point increase in the interest rate differential; bootstrapped one and two standard deviation confidence bands are obtained using 1 000 replications

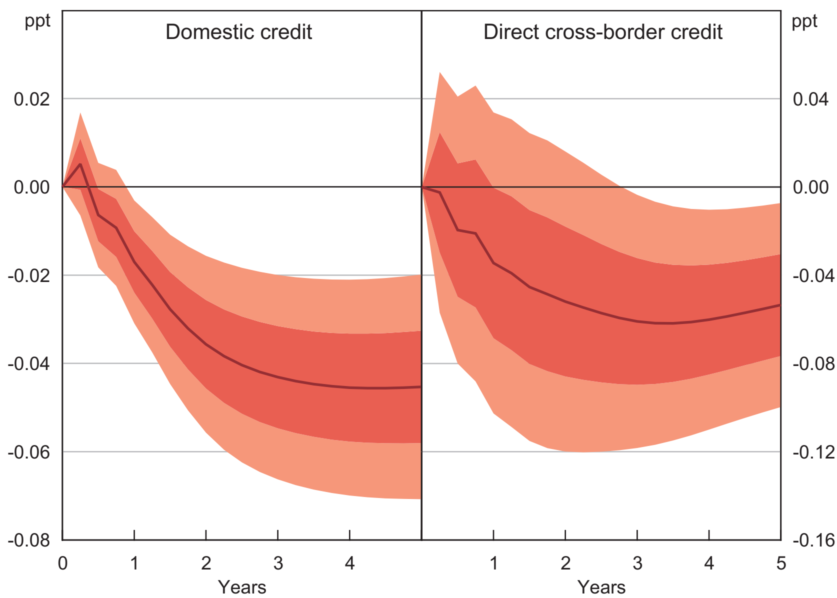
Figures 4 and 5 show that the effect of a depreciation of the Australian dollar and increased market 'fear', as captured by an increase in the VIX, have a very similar impact on credit flows and credit creation. They significantly reduce domestic credit creation and cross-border flows. The effects are all significant and long lasting.

Figure 4: Responses to a Change in the Exchange Rate



Notes: Responses to a 1 per cent increase in the AUD/USD exchange rate (domestic price of foreign currency; bootstrapped one and two standard deviation confidence bands are obtained using 1 000 replications

Figure 5: Responses to a Change in the VIX



Notes: Responses to a 1 per cent increase in VIX; bootstrapped one and two standard deviation confidence bands are obtained using 1 000 replications

Some differences, however, are worth highlighting: while the reduction in the provision of domestic credit that follows a depreciation in the local currency reverses after the first two years, the effect is much more persistent when market 'fear' increases. In both cases, the availability of cross-border flows is immediately affected. It therefore seems that shocks to the VIX are more important determinants of cross-border credit inflows to Australia (and of domestic credit creation) than interest rate spreads. This VAR analysis dovetails nicely with our cross-country panel regression results of the previous sections.

The complete set of impulse responses is provided at <http://www.rba.gov.au/publications/confs/2013/index.html>. They show that, as expected, both GDP and its deflator fall significantly when the VIX increases. On the other hand, the GDP deflator increases significantly when direct cross-border credit flows go up.

6. Conclusions

We presented cross-country panel regressions on the determinants of cross-border credit flows and property prices for a panel of small open economies with floating exchange rates. We also presented evidence on the determinants of house prices. The VIX is highly correlated with credit inflows and with asset prices. We also provided a VAR analysis of the interaction between monetary policy, credit flows and the VIX for Australia. While our interpretation of the VAR is subject to accepting our identification restrictions implicit in the order of the variables, we read the data as consistent with the fact that tranquil periods in international financial markets (reflected in the low value of the VIX) are associated with more credit flows into Australia. This in turn boosts credit creation in the economy. Larger inflows are also associated with an appreciating exchange rate. The effect of fluctuations in the VIX seems to be a powerful determinant of domestic credit and cross-border credit flows; in particular, it is more potent than interest differentials between Australia and the United States. Decreases in the VIX are also associated with increased GDP and a higher GDP deflator. Furthermore, it has been found elsewhere that lowering the federal funds rate is associated with a fall in the VIX (with a lag). There is, therefore, some potential for a feedback loop between monetary policy (spread between the Australian policy rate and the US rate), capital flows and credit creation. This type of feedback loop may sustain a prolonged departure from uncovered interest parity.

An extreme example of this mechanism, as noted in Plantin and Shin (2011), is Iceland. The high interest rate differential in Iceland fuelled capital inflows via the issuance of 'glacier bonds' that were used to fund investment projects in Iceland. Such large inflows led to a sharp appreciation in the krona and an overheating economy leading to an increase in policy rates. But the higher interest rate differential attracted more capital inflows that fuelled the booming economy.

It is important to gain a better understanding of what determines the potency of the feedback loop that sustains credit flows and prolonged departure from uncovered interest parity. Clearly the expenditure switching role of the exchange rate has to be rather weak for the loop to operate and the expansionary effect of capital flows fuelled by low volatility and risk aversion rather strong. Which other factors also determine fluctuations in risk and in credit flows is an interesting open question.

Appendix A: Data

Cross-sectional analysis

Domestic credit: constructed as the sum of domestic claims of depository corporations excluding central banks. Domestic claims are defined as claims on private sector, public non-financial corporations, other financial corporations and net claims on central or general government (claims less deposits). *Source*: Other Depository Corporation Survey and Deposit Money Banks Survey; Monetary Statistics; International Financial Statistics (International Monetary Fund (IMF)). Underlying data in national currencies.

Direct cross-border credit: measured as claims of all BIS reporting countries on all sectors, and bank and non-bank sectors of a given country in all currencies. *Source*: Bank for International Settlements (BIS), locational banking statistics, Tables 7A and 7B. Data are in US$ million, end-of-period, converted with respective end-of-period exchange rate.

Cross-border credit flows: exchange rate adjusted change in claims of all BIS reporting countries on all sectors, and bank and non-bank sectors of a given country in all currencies. *Source*: BIS, locational banking statistics, Tables 7A and 7B. Data are in US$ million, amounts outstanding at the end of the current and the previous period are converted into their original currency components using the respective end-of-period exchange rates. The differences between these individual components are subsequently converted back into US dollars using average exchange rates during the period.

Local volatility: volatility of stock price index, measured as the 360-day standard deviation of the return on the national stock market index. *Source*: Bloomberg and Global Financial Development Database (World Bank); annual data.

Equity growth: measured as a percentage, return on assets of commercial banks using net income to yearly averaged total assets. *Source*: Bankscope (Bureau van Dijk) and Global Financial Development Database (World Bank); annual data.

Debt-to-GDP ratio: central government debt as a per cent of GDP. *Source*: Haver Analytics and national statistical offices.

Stock market indices: end-of-period close quotes of national stock market indices. *Source*: Global Financial Data and Haver Analytics.

Nominal effective exchange rate: broad effective exchange rate indices. *Source*: BIS.

Inflation: CPI All Items quarterly inflation. *Source*: International Financial Statistics (IMF).

House price indices: *Source*: BIS and OECD.

Nominal GDP data in USD: original data in national currencies from national statistical offices; converted by Haver Analytics with respective end-of-period exchange rate.

VAR analysis

Australian GDP deflator: Australian Bureau of Statistics.

Australian credit: Australian Bureau of Statistics.

All other Australian variables: Haver Analytics.

References

Abhyankar A, A Gonzalez and O Klinkowska (2012), 'Salvaging the C-CAPM: Currency Carry Trade Risk Premia and Conditioning Information', Paper presented at the Society for Economic Dynamics Annual Meeting, Limassol, 22–24 June.

Avdjiev S, RN McCauley and P McGuire (2012), 'Rapid Credit Growth and International Credit: Challenges for Asia', BIS Working Papers No 377.

Bacchetta P and E van Wincoop (2010), 'Infrequent Portfolio Decisions: A Solution to the Forward Discount Puzzle', *The American Economic Review*, 100(3), pp 837–904.

Bekaert G, M Hoerova and M Lo Duca (2012), 'Risk, Uncertainty and Monetary Policy', European Central Bank Working Paper Series No 1565.

Borio C and P Disyatat (2011), 'Global Imbalances and the Financial Crisis: Link or No Link?', BIS Working Papers No 346.

Brunnermeier MK, S Nagel and LH Pedersen (2008), 'Carry Trades and Currency Crashes', *NBER Macroeconomics Annual*, 23(1), pp 313–348.

Bruno V and HS Shin (2013a), 'Capital Flows, Cross-Border Banking and Global Liquidity', NBER Working Paper No 19038.

Bruno V and HS Shin (2013b), 'Capital Flows and the Risk-Taking Channel of Monetary Policy', NBER Working Paper No 18942.

Burnside C, M Eichenbaum, I Kleshchelski and S Rebelo (2011), 'Do Peso Problems Explain the Returns to the Carry Trade?', *The Review of Financial Studies*, 24(3), pp 853–891.

Calvo GA, L Leiderman and CM Reinhart (1996), 'Inflows of Capital to Developing Countries in the 1990s', *The Journal of Economic Perspectives*, 10(2), pp 123–139.

Cetorelli N and LS Goldberg (2012), 'Banking Globalization and Monetary Transmission', *The Journal of Finance*, 67(5), pp 1811–1843.

CIEPR (Committee on International Economic Policy and Reform) (2012), *Banks and Cross-Border Capital Flows: Policy Challenges and Regulatory Responses*, Brookings Institution, Washington DC.

Fama EF (1984), 'Forward and Spot Exchange Rates', *Journal of Monetary Economics*, 14(3), pp 319–338.

Farhi E and X Gabaix (2011), 'Rare Disasters and Exchange Rates', unpublished manuscript, Harvard University.

Forbes KJ and FE Warnock (2012), 'Capital Flow Waves: Surges, Stops, Flight, and Retrenchment', *Journal of International Economics*, 88(2), pp 235–251.

Frankel JA (1983), 'Monetary and Portfolio-Balance Models of Exchange Rate Determination', in JS Bhandari and BH Putnam with JH Levin (eds), *Economic Interdependence and Flexible Exchange Rates*, The MIT Press, Cambridge, pp 84–115.

Gagnon JE and AP Chaboud (2007), 'What Can the Data Tell Us About Carry Trades in Japanese Yen?', Board of Governors of the Federal Reserve System International Finance Discussion Paper No 899.

Galati G, A Heath and P McGuire (2007), 'Evidence of Carry Trade Activity', *BIS Quarterly Review*, September, pp 27–41.

IMF (International Monetary Fund) (2012), *Annual Report on Exchange Arrangements and Exchange Restrictions*, IMF Publication Services, Washington DC.

Jorda O and AM Taylor (2012), 'The Carry Trade and Fundamentals: Nothing to Fear but FEER Itself', *Journal of International Economics*, 88(1), pp 74–90.

Lustig H, N Roussanov and A Verdelhan (2010), 'Countercyclical Currency Risk Premia', NBER Working Paper No 16427.

Lustig H and A Verdelhan (2007), 'The Cross Section of Foreign Currency Risk Premia and Consumption Growth Risk', *The American Economic Review*, 97(1), pp 89–117.

Miranda Agrippino S and H Rey (2012), 'World Asset Markets and Global Risk Aversion', Paper presented at the Joint ECB-BIS workshop 'Global Liquidity and its International Repercussions', Frankfurt, 6–7 February.

Plantin G and HS Shin (2011), 'Carry Trades and Speculative Dynamics', unpublished manuscript, Toulouse School of Economics.

Rajan RG (2005), 'Has Financial Development Made the World Riskier?', in *The Greenspan Era: Lessons for the Future*, A Symposium sponsored by the Federal Reserve Bank of Kansas City, Kansas City, pp 313–369.

Reinhart CM and VR Reinhart (2009), 'Capital Flow Bonanzas: An Encompassing View of the Past and Present', in JA Frankel and C Pissarides (eds), *NBER International Seminar on Macroeconomics 2008*, University of Chicago Press, Chicago, pp 9–62.

Rey H (2013), 'Dilemma not Trilemma: The Global Financial Cycle and Monetary Policy Independence', Paper presented at the Federal Reserve Bank of Kansas City Economic Policy Symposium on 'Global Dimensions of Unconventional Monetary Policy', Jackson Hole, 22–24 August.

Shin HS (2012), 'Global Banking Glut and Loan Risk Premium', *IMF Economic Review*, 60(2), pp 155–192.

Sighvatsson A (2007), 'Paddling in an Ocean of Global Money: The Problems of Running Independent Monetary Policy in a Very Small Open Economy at Times of Large Demand Shock and Ample Global Liquidity', Paper presented at the Central Bank of Iceland – International Monetary Fund Conference 'The Challenges of Globalisation for Small Open Economies with Independent Currencies', Reykjavic, 31 May–1 June.

Truempler K (2013), 'On the Carry Trade in Small Open Economies', unpublished manuscript, London Business School.

Vasicek O (2002), 'Loan Portfolio Value'. *Risk*,15(12), pp 160–162.

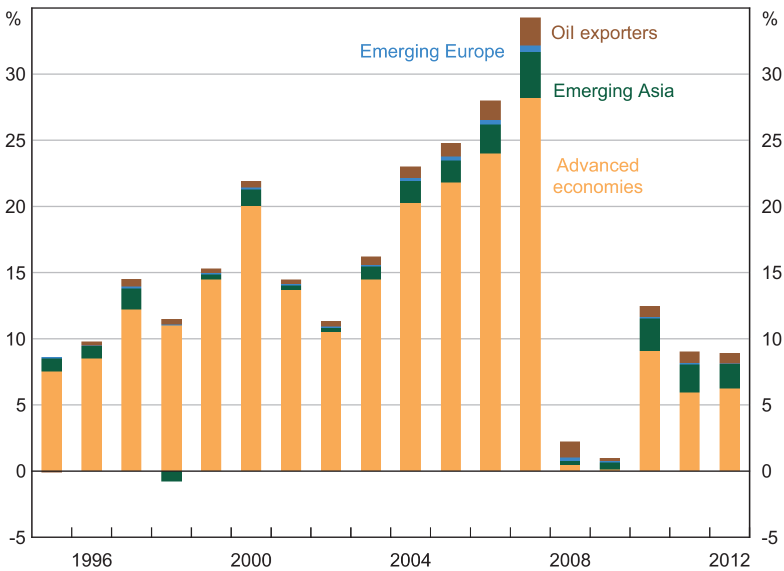
Discussion

1. Piti Disyatat

Let me begin by noting two striking observations. First, in the decade leading up to the global financial crisis, there was an enormous expansion in gross capital flows (Figure 1). At the peak in 2007, the sum of gross inflows and outflows amounted to as much as 35 per cent of world GDP. This compares with net flows (i.e. current accounts) that, when summed up across economies, make up at most around 3–4 per cent of world GDP.

Figure 1: Gross Capital Flows

Per cent of world GDP



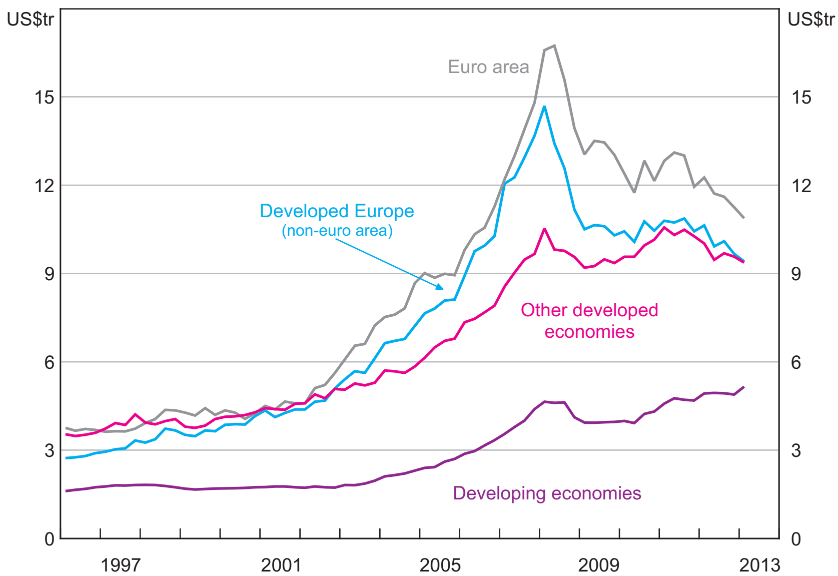
Notes: Advanced economies = Australia, Canada, Denmark, euro area, Japan, New Zealand, Sweden, the United Kingdom and the United States; emerging Asia = China, India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan and Thailand; emerging Europe = Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovak Republic and Slovenia; oil exporters = Algeria, Angola, Azerbaijan, Bahrain, Democratic Republic of the Congo, Ecuador, Equatorial Guinea, Gabon, Iran, Kazakhstan, Kuwait, Libya, Nigeria, Norway, Oman, Qatar, Russia, Saudi Arabia, Sudan, Syria, Trinidad and Tobago, United Arab Emirates, Venezuela and Yemen

Source: IMF

The bulk of this explosion in gross flows is due to cross-border trades in financial instruments. For example, consider the case of an Australian bank that issues a US dollar bond offshore to non-residents. On the one hand, non-resident claims on Australia increase: thus there is a gross inflow into Australia. On the other hand, the Australian bank has acquired US dollars, which is a claim on non-residents: thus there is a gross outflow. Hence, financial transactions such as these typically involve two-way gross flows. Notice that the current account and net capital flows are unaffected in all this. Looking at developments in gross flows is much more informative about cross-border financial flows and intermediation than focusing on net flows (see Borio and Disyatat (2011) for detailed discussion).

Second, the last decade has also witnessed a large boom in cross-border banking. This is illustrated in Figure 2 which plots the external claims of BIS reporting country banks on borrowers in different regions. The run-up was particularly large in advanced economies, especially among countries in the euro area, though developing economies also saw persistent uptrends in such flows. These flows have become an increasingly important component of gross capital flows and have large financial stability implications.

Figure 2: Boom in Cross-border Banking



Note: External loans and deposits of BIS reporting country banks on borrowers in country group listed
Source: BIS locational banking statistics, Table 7A

What I like very much about Miranda Agrippino's and Rey's paper is the focus on gross capital flows and on banking flows.

The overall goal of the paper is to study the link between cross-border banking flows, global risk, credit and asset prices in carry-trade recipient economies. The analysis is carried out in three separate parts that seek to investigate: (i) the determinants of banking inflows; (ii) the impact of inflows on property prices; and (iii) the dynamic response of domestic and external credit to interest rate, exchange rate and VIX shocks.

The analysis is done well and I have no major issues with the estimation or the results, which are largely in line with previous studies (see, for example, Bruno and Shin (2013)). My comments will focus largely on two issues: (i) the heavy emphasis on carry trades as the key motivation for the paper; and (ii) the lack of a clear description of the underlying transmission mechanism between capital inflows and domestic credit expansion.

The carry-trade focus

A key motivation for the paper is to study the impact of capital inflows in carry-trade recipient countries. The authors use the criterion of 'perceived' carry-trade recipient as a basis for selecting the sample of countries in the study. The main problem with such an approach is that carry trades are notoriously hard to pin down. There are a number of ways to implement such trades and much of these involve the use of derivatives, which are off-balance sheet items (see, for example, Galati, Heath and McGuire (2007)). Moreover, carry trades are often indistinguishable from other flows. For example, a long Australian dollar/short Japanese yen carry trade is typically implemented by entering into a forward contract to buy Australian dollars against yen at some point in the future. Such a position is *identical* to one that would arise from an Australian exporter to Japan who wishes to hedge his anticipated Japanese yen export receipts back into Australian dollars.

The paper does not specify exactly what criteria are used to determine carry-trade recipient countries. Presumably high interest rates would be one key factor, but the question is relative to whom? And for a sample period of over 10 years it is hardly the case that such relative interest differentials will be stable. So a given country may be a carry-trade recipient in some periods and a funding currency in another. Indeed, in almost all of the specifications in the paper, interest differentials are not a significant determinant of capital inflows.

Moreover, there are formidable data shortcomings when it comes to identifying carry trades. The Bank for International Settlements (BIS) banking statistics used in the study only cover on-balance sheet positions. Hence, much of the carry-trade activity, which is typically implemented through the forward market, is not captured. It is also not possible to distinguish carry-trade positions from those arising from general borrowing and lending by firms and households. Finally, a carry trade specifically involves two currencies where the exposure to exchange rate risk is a key part of the strategy. As such, the analysis should strictly focus on non-resident claims on *local* currency only, as opposed to total claims as in the paper.

The upshot is that it is not quite clear what the country grouping, which in the sample includes disparate countries such as Canada, Iceland, Mexico and Norway, really represents. That said, the countries in the sample all did experience substantial banking inflows. In this respect, the paper would be improved if the carry-trade focus were downplayed and if it were motivated more generally as a study of the behaviour and impact of banking inflows in a set of countries where such inflows have been high.

Capital inflow and domestic credit

There is a recurring implicit assumption throughout the paper that banking inflows from abroad lead to an expansion of domestic credit. This is especially so in the VAR analysis, which attempts to go beyond the analysis of correlations in the first two sections of the paper to ascertain some direction of causation from banking inflows to domestic credit. While the results do seem to support this, it would be useful if the paper clearly laid out conceptually how such a link may work in practice. The main sticking point here is that there is no *direct* link between capital inflows (banking or otherwise) and *domestic currency* credit. In particular, capital inflows do not expand the supply of domestic currency funds available for lending.

The supply of domestic currency funds in terms of the deposit base in *local currency* is largely dictated by the pace at which domestic banks extend loans. As domestic banks extend loans, local currency deposits are created. Capital inflows simply entail the acquisition of such deposits from someone else. Local currency deposits simply change hands and the aggregate size is unchanged. Those deposits, of course, represent domestic purchasing power which can be used to buy local assets or extend loans. Thus capital inflows may enhance or lengthen the intermediation chain of domestic funds, but do not create new purchasing power. The influence that capital inflows have on domestic credit must be indirect, through their impact on relative yields and risk perceptions, rather than a direct relaxation of some quantitative constraint on lending capacity.

Of course, capital inflows can directly expand *foreign currency* credit. For this to materially affect domestic spending requires that a domestic resident be willing to undertake foreign exchange rate risk. While this has occurred in some countries, such as the central and eastern European countries, the substantial risks involved should limit the extent that this can, or is allowed to, take place.

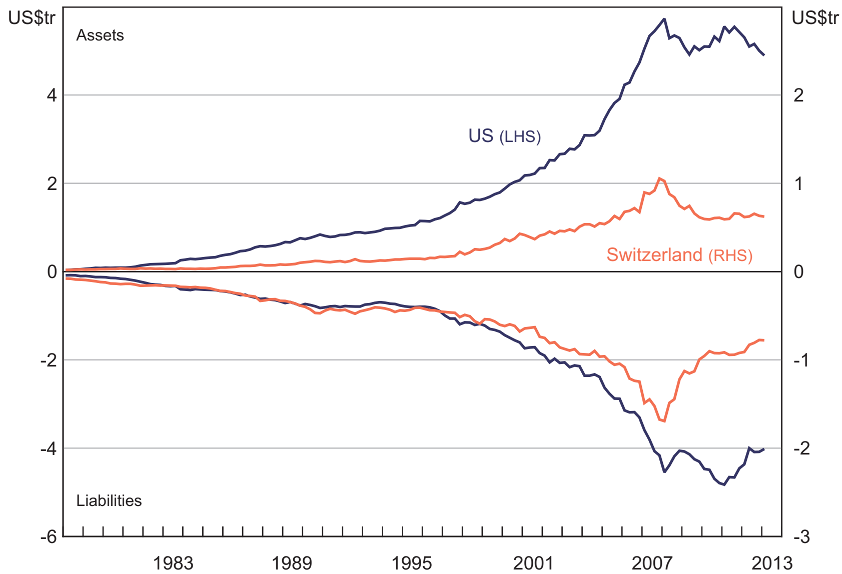
Rather than viewing banking inflows as driving domestic credit as the paper does, one distinct possibility is that variations in banking inflows simply reflect the intermediation of domestic credit largely driven by variations in local economic prospects. The sustained expansion in cross-border banking flows in the lead-up to the financial crisis reflects a lengthening of the intermediation chain in many countries in an increasingly globalised financial system. Thus variation in banking flows is the 'tail of the dog', so to speak, largely dancing to the tune of changes in local credit expansion.

For example, take the case of Australia where domestic banks obtain around 30 per cent of their funding from abroad. When a loan is granted to a domestic resident, banks may seek to fund this through foreign borrowing. Alternatively, suppose a domestic resident wants to obtain foreign currency to finance direct investment abroad from a local bank. The domestic banking system may obtain the foreign currency by borrowing abroad (usually through the swap market). In both cases, there will be expansions in cross-border inflows that reflect the intermediation of credit and associated currency hedging activities. Ultimately, regardless of whether it is funded domestically or internationally, the extension of domestic bank credit is a decision of domestic banks based on local needs.

More generally, the direction of causality of the global factor highlighted in the paper deserves further scrutiny. The importance of the VIX in explaining capital flows is certainly striking. This has also been documented in numerous studies. The paper interprets this as indicating an important role for global factors in driving capital inflows. The image is one of an 'ocean of liquidity' being pushed into countries driven by variations in the VIX. The question is what the VIX really represents. After all, the investor sentiment that it captures is endogenous and closely related to real economic developments. One possibility is that variations in the VIX proxy for incoming news about the state of the global economy, which obviously has important ramifications for the domestic economies of various jurisdictions. This, in turn, may lead to changes in local credit demand and supply. The related changes in banking inflows then simply reflect the changes in cross-border intermediation associated with this. That is, the ebb and flow of cross-border banking is a reflection of variations in local credit extension rather than being their driver.

Figure 3 shows, for example, that even for countries typically associated with 'funding currencies' in carry-trade activity, there is substantial banking inflow. These largely mirror outflows. An examination of recipient countries also reveals the two-way nature of capital flows that reflect the cross-border intermediation function of banks. As such, it is quite difficult to disentangle the chicken from the egg and get a clear picture of causality.

Figure 3: Increase in Bank External Positions in Funding Countries



Note: Summed by sector-country pair for reporting banks
Source: BIS locational banking statistics, Table 6A

The key issue at stake here ultimately is how policy should respond. If capital inflows are seen as driving domestic credit, then one might be inclined to argue for some sort of control to be put in place to alleviate perceived negative effects, not least the complications that they pose for monetary policy. On the other hand, if the ebbs and flows of cross-border banking reflect the intermediation of domestic credit that is largely driven by local economic conditions and needs, then it is not clear that they should be seen as something that must be limited. Ultimately, it is difficult to answer such questions without some views about the appropriate funding model of banks. Should they be predominantly deposit based or does wholesale funding offer worthwhile efficiency gains? The paper is largely silent on these issues.

References

Borio C and P Disyatat (2011), 'Global Imbalances and the Financial Crisis: Link or No Link?', BIS Working Papers No 346.

Bruno V and HS Shin (2013), 'Capital Flows, Cross-Border Banking and Global Liquidity', Princeton University, Griswold Center for Economic Policy Studies Working Paper No 237a.

Galati G, A Heath and P McGuire (2007), 'Evidence of Carry Trade Activity', *BIS Quarterly Review,* September, pp 27–41.

2. General Discussion

The discussion of the paper presented by Hélène Rey began with several comments about its framing and interpretation. In response to comments by Piti Disyatat in his discussion, Professor Rey confirmed that the VIX was certainly not exogenous. Rather, she stated that other studies that used either a recursive VAR or structural VAR framework found that the effects of the VIX on capital flows and asset prices were attributable to the US federal funds rate. Another participant asked whether other volatility measures might be better explanators of capital flows. Professor Rey responded that she planned to test this, but given the high degree of correlation across different volatility measures, she suspected any candidate measures would be strongly correlated with the VIX and therefore unlikely to provide much further insight.

The precise nature of the carry trade, and its relationship to volatility, was raised by several participants. A number of participants suggested that the pre-2007 carry trade followed a classic interest rate differential motive, for example private Japanese investors taking Australian and New Zealand bond risk and transacting in basis swaps with banks, that had little intuitive relationship with the VIX. This was contrasted against the risk-on/risk-off environment that had characterised financial markets since the start of the financial crisis. In particular, over this period the role of the VIX had been clearer, with a high correlation across many asset prices, including the Australian and New Zealand dollar exchange rates and the S&P 500. It was also suggested that current cross-border financial flows were primarily the result of balance sheet expansion as a side effect of unconventional monetary policy, rather than a response to prices in the form of interest rate differentials. Several participants expressed their surprise that the VIX mattered at all in the pre-financial crisis period, with one questioning why the VIX would matter given that the carry trade prior to 2007 primarily used yen as a funding currency and did not involve the US dollar. Another noted that the relationship between risk and the Australian dollar had been unstable over recent years; notable appreciations and depreciations had both occurred in risk-off periods, suggesting that the motivation for capital flows were broader than the carry trade alone. In response, Professor Rey noted that the term 'carry trade' was meant loosely, both because only a subset of countries in the paper's sample were typical carry trade economies, and because the analysis of the paper was more general than this specific yield-seeking activity. She suggested that the VIX could be relevant, despite transactions not necessarily being denominated in US dollars, because of the importance of the US dollar and the federal funds rate in affecting leverage of financial intermediaries in the global banking system. She noted this had echoes of the Calvo, Leiderman and Reinhart (1996) result that capital inflows to Latin America were associated with weak global economic conditions and low interest rates.

Another participant asked if splitting the sample group of countries according to different characteristics, such as the degree of exchange rate flexibility, would demonstrate varying sensitivities of capital flows to the VIX. They suggested that while the underlying economic arguments were unaffected, it seemed plausible that volatility of capital flows increased with flexibility of the exchange rate and ease of transacting in the currency because investment managers would be able to take manageable cross-border risk more effectively. Professor Rey agreed that looking at financially sophisticated countries in more detail was worthwhile because the exchange rate played an important role.

Picking up on comments made by the discussant, one participant asserted that global banks were very important intermediaries for small open economies, and it was imperative that regulation aimed at producing better long-run outcomes in financial markets did not undermine this role. They noted that local banks in periphery jurisdictions tended to have substantial directional positions, so global banks were needed to take the other side of these positions, effectively providing financial intermediary services to economies such as Australia and New Zealand. While this intermediation led to an increase in banking flows, this was not necessarily a negative outcome.

Reference

Calvo GA, L Leiderman and CM Reinhart (1996), 'Inflows of Capital to Developing Countries in the 1990s', *The Journal of Economic Perspectives*, 10(2), pp 123–139.

Bank Funding and Financial Stability

Prasanna Gai, Andrew G Haldane, Sujit Kapadia and Benjamin Nelson*

1. Introduction

The crisis of 2007–2008 was a crisis of collateral. Since then, financial market participants – particularly in the euro area and the United States – have shown an increased appetite for secured lending. In short-term bank funding markets, there has been a pronounced shift towards repurchase arrangements. And covered bonds have gained in popularity in long-term funding markets. The cyclical flight to safety, driven by market forces, has been reinforced by regulatory developments. These include reforms to over-the-counter derivative markets that emphasise more stringent collateralisation, preferential regulatory treatment of covered bonds, and the prospect of statutory 'bail-in' tools for financial regulators.

The financial stability implications of increased collateralisation of financial transactions and rising bank asset encumbrance levels remain poorly understood. From a *microprudential* perspective, secured funding – especially when long term – would appear desirable since it increases funding diversity and seemingly reduces funding liquidity risk particularly during periods of market stress.

From a *macroprudential* perspective, however, there are grounds to be less sanguine. High encumbrance levels, particularly if opaque, can reduce the assets available to unsecured creditors, leading to higher costs of borrowing from such funding sources and heightening incentives to finance on secured terms. And, as assets are increasingly encumbered, the financial system as a whole may become riskier as it is more susceptible to procyclical swings in the underlying value of the (increasingly common) collateral assets (Haldane 2012). During economic downturns, falling collateral values and higher haircuts require more assets to be pledged to raise a given level of funding. This, in turn, may necessitate reduced balance sheet leverage via asset sales, limit new banking activities and potentially heighten investor concern about bank viability.

In this paper, we present a simple analytical model of bank funding to shed some light on the relationship between liquidity risk, solvency risk, and collateral values. We apply ideas from the literature on global games (Morris and Shin 2003, 2010) to provide an accounting framework to decompose balance sheet risk and to solve for the rollover games being played by unsecured and secured creditors. In the model, total bank risk is decomposed into insolvency risk and illiquidity risk and the two are jointly determined as a function of the underlying parameters of the model. Although cast as a partial equilibrium treatment of a single bank, our analysis is nevertheless suggestive. The parameters that we treat as exogenous would become endogenous in a model of a banking system and reflect broader market and macroeconomic conditions. As such, they become natural channels for the transmission of financial stability problems.

* The views expressed herein are those of the authors and do not necessarily represent those of the Bank of England, its Financial Policy Committee or its Monetary Policy Committee. We would like to thank George Avil for excellent research assistance and Bernd Schwaab, Paul Tucker and participants at the RBA Annual Conference for helpful comments and suggestions.

Our analysis reveals the importance of the maturity of secured debt through the trade-offs faced by secured creditors. In the model, secured creditors have recourse to ring-fenced collateral in the form of a risky, illiquid asset and earn lower returns relative to unsecured creditors. A bank improves its profitability and thus solvency position by relying on long-term secured funding. But the impact on liquidity risk is ambiguous – while increased long-term stable funding improves *ex ante* liquidity risk by replacing fickle short-term debt, it also reduces the amount of unencumbered collateral that can be liquidated to service early withdrawals. If, instead, the bank seeks out short-term secured funding, interim liquidity risk and asset encumbrance become intimately intertwined. We show how factors that worsen the interim liquidity position of the bank lead secured creditors to endogenously demand more collateral which, in turn, compounds the likelihood of a run by unsecured creditors.

We are also able to obtain some simple comparative static results that shed light on the consequences of greater collateralisation of bank balance sheets for the procyclicality of the financial system. In our model, the liquidation or market value of collateral can be viewed as reflecting the state of the macroeconomy and the sensitivity to liquidity risk varies with collateral values. As banks strive to fund their operations via secured funding, their exposure to such liquidity risk can become greater than in the case where funding is by unsecured short-term debt alone. In particular, if too few assets are pledged as collateral, exposure to the risk of falls in the market value of collateral is heightened, even when secured funding is long term in nature. And when secured funding is short term, the endogeneity of asset encumbrance and the possibility of a dash for collateral exacerbate the sensitivity of liquidity risk to collateral values. In this context, we show that the imposition of minimum regulatory haircuts may reduce the sensitivity of a bank's liquidity position to variation in collateral values and thus the procyclical fluctuations generated by secured debt.

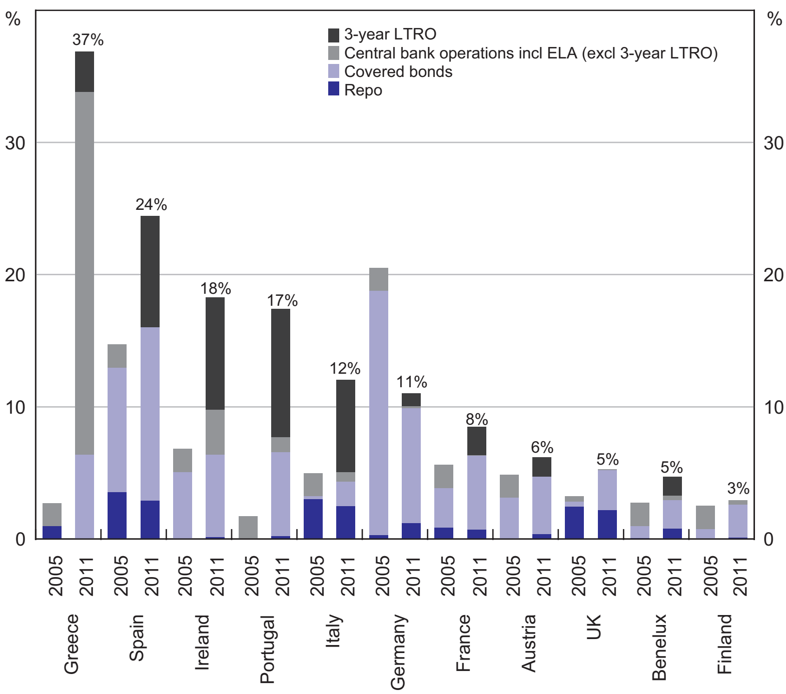
Notwithstanding considerable policy interest (e.g. CGFS 2013), the relationship between financial stability and asset encumbrance has received scant attention in the academic literature. Roland and Sowerbutts (2013) consider the factors driving asset encumbrance, such as Knightian uncertainty and the removal of implicit deposit guarantees. But their model does not consider the implications for bank liquidity risk or the impact of increased collateralisation for the procyclicality of the system. Anand, Chapman and Gai (2012) focus on covered bonds, and also use a global games approach to model the risk of a run by unsecured creditors. Following a shock, the balance sheet of the bank has to be adjusted to ensure the quality of ring-fenced assets backing the covered bond, and the critical threshold for a run depends on the extent of asset encumbrance and the liquidity of secured lending markets. Rinaldi (2011), like the present paper, also highlights the possibility of runs by secured creditors. But her focus is on the role played by ambiguity and ambiguity aversion in generating credit market freezes. Finally, a line of literature considers the amplification role of haircut shocks in generating procyclicality (e.g. Brunnermeier and Pedersen 2009; Adrian and Shin 2010; Geanakoplos 2010; Gorton and Metrick 2010; Gai, Haldane and Kapadia 2011) but typically does not consider this in light of the interplay between secured and unsecured debt or in the context of the move towards greater asset encumbrance.

The paper proceeds as follows. Section 2 presents some stylised facts on bank funding and asset encumbrance patterns, documenting some regulatory changes that are contributing towards increased collateralised borrowing. Section 3 outlines the model, and sets out how the liquidity risk of a bank changes with the composition of bank funding. We present the case of a bank financed solely with unsecured debt as a benchmark, and contrast the bank's liquidity risk in this case with the liquidity risk that obtains under long-term and short-term secured funding. Section 4 concludes with some policy implications in the context of the ongoing debate on regulatory reform.

2. Stylised Facts

Figures 1 and 2 show the extent to which wholesale bank funding in Europe has become increasingly collateralised. Prior to the crisis, collateralised debt and asset encumbrance were most prominent in countries with a long tradition in covered bonds (e.g. Germany and Spain). But by 2011, asset encumbrance had risen markedly in countries with strained finances, such as Ireland, Greece and Italy. Figure 2 illustrates the clear recent increasing trend in the encumbrance ratios, after a prolonged plateau, of Swedish banks. The shift to collateralisation by UK financial institutions has also been marked – the proportion of system assets encumbered rose to around 5 per cent by 2011, although alternative approaches to estimating encumbrance ratios can give figures of up to 20 per cent (Bank of England 2012).

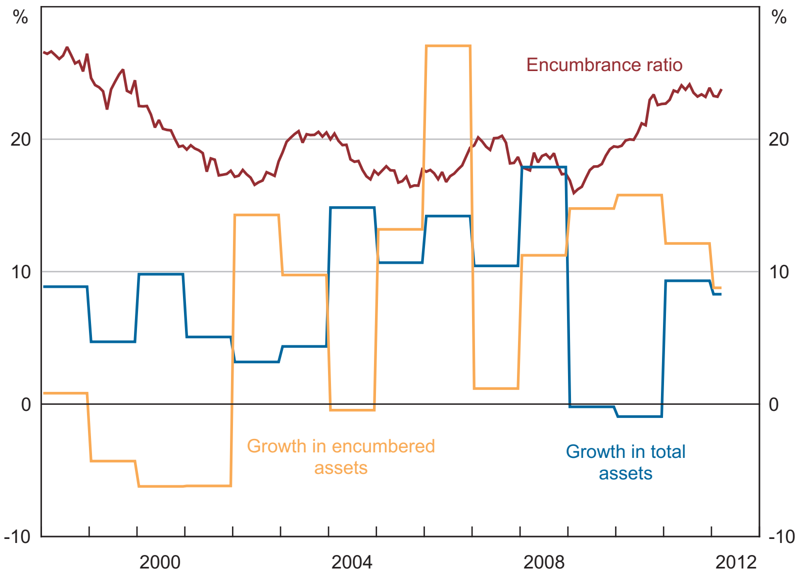
Figure 1: Proportion of System Balance Sheets Encumbered



Notes: Barclays Capital's estimates for the allocation of the combined 3-year LTRO (long-term refinancing operation) have been derived from Fransolet and Maraffino (2012, Figure 1); Barclays Capital's assumptions for haircuts/over-collateralisation are as follows: haircut on repo = 5 per cent, haircut on LTRO = 10 per cent and over-collateralisation of covered bonds = 30 per cent; ELA denotes emergency liquidity assistance

Sources: Barclays Capital (taken from Harrison and Samuels (2012)); European Central Bank; European Covered Bond Council

Figure 2: Sweden – Encumbrance Trend



Notes: Encumbrance ratio is a ratio of outstanding covered bonds to total assets adjusted for 30 per cent of over-collateralisation; data includes Swedish banks and mortgage institutions
Sources: Statistics Sweden; Sveriges Riksbank (taken from Juks (2012))

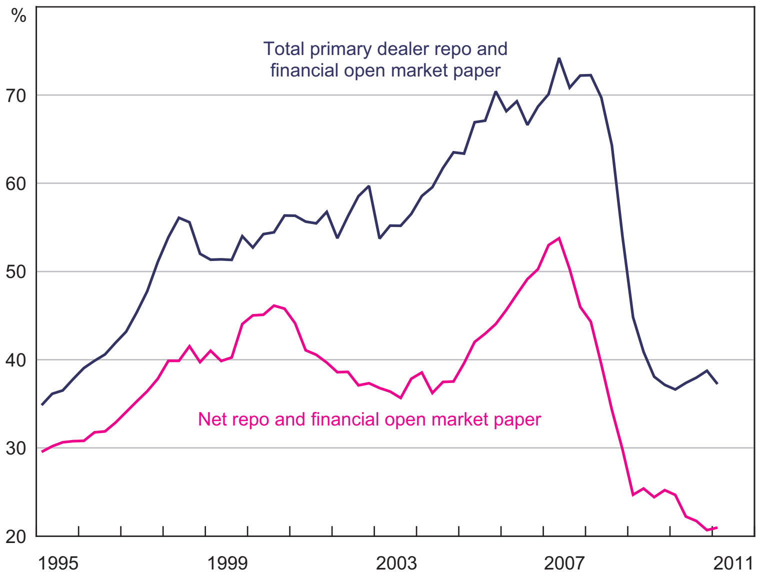
Table 1 shows how the reliance on long-term secured lending, in the form of covered bonds, has increased in a number of countries. Meanwhile, US banks remain significantly reliant on short-term secured funding – for example, net repos and financial market open paper stood at around 20 per cent of total retail deposits in 2011 (Figure 3). At the same time, it should be noted that one counterpart to these overall trends has been the shrinkage of private-sector asset-backed securities markets.

Table 1: Outstanding Amounts of Covered Bonds Backed by Mortgage Assets
€ million

Country	2003	2005	2007	2009	2010	2011	2012
Canada			2 000	7 525	18 003	38 610	49 121
Denmark	204 695	246 411	244 696	319 434	332 505	345 529	359 560
France	21 079	32 133	63 555	134 757	156 239	198 395	208 297
Germany	256 027	237 547	206 489	255 100	219 947	223 676	215 999
Italy				14 000	26 925	50 768	116 405
Netherlands		2 000	15 973	29 057	41 273	54 115	61 515
Spain	57 111	150 213	266 959	336 750	343 401	369 208	406 736
Sweden			92 254	133 903	188 750	208 894	220 374
United Kingdom	5 000	28 384	84 874	200 466	203 215	185 052	185 243

Source: European Covered Bond Council (adapted from CGFS (2013, p 7))

Figure 3: United States – Repos and Financial Open Market Paper
Per cent of M2



Sources: Bank of England; Board of Governors of the Federal Reserve System; Federal Reserve Bank of St. Louis

Figure 3 also illustrates how collateralised debt and, in particular, the haircuts associated with it play a key role in procyclical behaviour. Prior to the crisis, haircuts were extremely compressed and marginal leverage was relatively high. But as haircuts rose sharply during the crisis, the subsequent decline in marginal leverage reinforced the downturn in the credit cycle. Although data on haircuts are sparse, there is reason to believe that they exhibit procyclicality. Table 2 presents the best available information on the evolution of haircuts on collateralised lending during the global financial crisis – haircuts on some securities financing transactions rose by up to 90 percentage points between 2007 and 2009.[1]

1 For a more detailed explanation of the role of haircuts, why these haircuts might fluctuate, and further empirical evidence, see Gorton and Metrick (2010). Additional empirical evidence of cyclicality in underlying haircuts is also given by Geanakoplos (2010) and Krishnamurthy (2010).

Table 2: Typical Haircut on Term Securities Financing Transactions
Per cent

	June 2007			June 2009		
	Prime[a]	Non-prime[b]	Unrated[c]	Prime[a]	Non-prime[b]	Unrated[c]
G7 government bonds						
Short-term	0	0	0.5	0.5	1	2
Medium-term	0	0	0.5	1	2	3
US agencies						
Short-term	1	2	3	1	2	3
Medium-term	1	2	3	2	5	7
Pfandbrief	0	0	1	1	2	8
Prime mortgage-backed securities						
AAA-rated	4	6	10	10	20	30–100
AA- and A-rated	8	12	25	100	100	100
Asset-backed securities	10	20	20	25	50	100
Structured products (AAA)	10	15	20	100	100	100
Investment-grade bonds						
AAA- and AA-rated	1	2	5	8	12	15
A- and BBB-rated	4	7	10	10	15	20
High-yield bonds	8	12	20	15	20	40
Equity						
G7 economies	10	12	20	15	20	25
Emerging economies	15	20	35	20	25	40

Notes: Data were gathered by a CGFS Study Group during bilateral interviews with market participants; a 100 per cent haircut implies that the relevant market was effectively closed

(a) Prime counterparty

(b) Non-prime counterparty

(c) Hedge funds and other unrated counterparties

Source: CGFS (2010)

A number of recent regulatory changes suggest that the trend towards secured wholesale funding seems set to continue (see also Bank of England (2012)). First, the G20 has mandated that standardised OTC derivative contracts be centrally cleared. While not directly increasing secured funding, the increased posting of collateral that this entails will increase asset encumbrance and expose financial firms to fluctuations in collateral values.

Second, covered bonds have preferential regulatory treatment both because they are included as Level 2 assets under the new Liquidity Coverage Ratio of Basel III, and because reforms for insurers under Solvency II will require insurance companies to have less capital against exposure to covered bonds than against unsecured debt with the same issuer. These regulatory rules might serve as an incentive to banks to increase their use of covered bonds.

Third, depositor preference can reduce recovery values for unsecured creditors and, so, make secured funding more attractive to issue. Law in Australia, as well as in the United States and Switzerland, already establishes depositor preference. The European Council has recently agreed to introduce tiered depositor preference into the bank resolution framework. And legislation is being introduced in the United Kingdom to give insured depositors preference above unsecured creditors in a debt workout.

Finally, new crisis resolution frameworks are likely to include a statutory 'bail-in' tool that would allow resolution authorities to write down unsecured debt or convert it to equity when a distressed bank enters resolution. Covered bonds and other forms of secured debt are excluded from writedowns under some frameworks and, while not changing the position of unsecured debtholders in the creditor hierarchy, bail-in makes it more likely that unsecured creditors will suffer losses should a large, complex financial firm fail. At the same time, it should be noted that likely future requirements on systemically important financial institutions to maintain an adequate amount of gone-concern loss-absorbing capacity in resolution (FSB 2013a) should counter some of these tendencies to move away from unsecured debt.

3. Analytical Framework

Our framework is inspired by Morris and Shin (2010) and describes how the *insolvency* and *illiquidity* risks of a financial institution are influenced by the way it funds its business activities. In particular, we highlight how a shift from unsecured to secured funding affects both the level of bank risk and its sensitivity to fluctuations in collateral values. We also distinguish between short-term and long-term secured funding and model 'dashes for collateral' by secured creditors.

3.1 Unsecured funding

The bank's balance sheet takes the simple form in Morris and Shin (2010). On the asset side, the bank holds two assets: cash, M, and Y units of a risky asset, such as loans or risky securities. The funding for these assets comes from short-term unsecured debt, D, and equity, E. Accordingly,

$$M+Y=D+E. \tag{1}$$

There are three dates, $\tau = 0, 1, 2$. Each unit of the risky asset pays a gross amount θ_2 in date 2, so the bank is solvent at the final date if *ex post* equity is positive, that is

$$\theta_2 Y+M-D_2 \geq 0, \tag{2}$$

where D_2 is the date-2 face value of unsecured debt. Equivalently, we can define a critical return or 'solvency point' for the bank:

$$\theta^{**} \equiv \frac{D_2-M}{Y}. \tag{3}$$

We assume that if the bank is insolvent at date 2, i.e. $\theta_2 < \theta^{**}$, then the bank goes into liquidation and the creditors do not receive any pay-off.

At the interim date, unsecured creditors must decide whether to roll over their lending. The bank can liquidate cash and its holdings of risky assets to service withdrawals by its creditors – cash is liquidated at par, but risky assets fetch an amount $\psi \in [0, 1]$ when liquidated. The interim resources available to the bank are therefore:

$$M+\psi Y. \tag{4}$$

If the proportion of creditors that choose not to roll over their loans is $\lambda \in [0, 1]$, the bank fails from a run at the interim date if the debt withdrawn exceeds interim resources. That is:

$$\lambda D \geq M+\psi Y. \tag{5}$$

When Equation (5) holds with equality, we can define the bank's 'liquidity ratio', as:

$$\lambda^* \equiv \frac{M+\psi Y}{D}. \tag{6}$$

As λ^* rises, a run is less likely to result in failure. In keeping with the global games literature, we suppose that unsecured creditors believe that the proportion of creditors that do not roll over their loans is uniformly distributed over the interval [0, 1]. If the bank fails because of a run, creditors that do not withdraw receive nothing (zero recovery). Accordingly, each creditor believes that the probability of a run being successful is $1 - \lambda^*$.[2]

We also can relate the solvency point and liquidity ratio to key balance sheet ratios using Equation (1). In particular, dividing through by Y,

$$d=m+(1-e), \tag{7}$$

where $d \equiv \frac{D}{Y}, m \equiv \frac{M}{Y}, e \equiv \frac{E}{Y}$ reflecting the bank's short-term debt ratio, the cash-asset ratio and the risk-weighted equity ratio (assuming a zero risk-weight on cash and a weight of unity on risky assets). The solvency point can thus be expressed as

$$\theta^{**}=(r-1)m+r(1-e), \tag{8}$$

where $r \equiv D_2/D$ is the return on unsecured debt. As θ^{**} rises, insolvency becomes more likely. So a higher cash-asset ratio, a lower equity ratio, or a higher interest rate all make insolvency more likely.

In a similar vein, the liquidity ratio can be expressed as:

$$\lambda^*=\frac{m+\psi}{m+(1-e)}. \tag{9}$$

A higher equity ratio (and hence less debt financing) makes the bank less likely to suffer from interim liquidity shortages. Note also that the higher the liquidation value of the risky asset, the less likely is a bank run:

$$\frac{\partial \lambda^*}{\partial \psi}=\frac{1}{m+(1-e)}. \tag{10}$$

2 If the expected value of date-2 returns is θ_1 at date 1, and creditors observe noisy signals, $x_i = \theta_1 + \sigma\eta_i$, with η_i distributed according to some density and σ governing the noise, there exists a unique equilibrium threshold signal x^* above which creditors roll over and below which creditors withdraw. If θ_1 is uniform, then a creditor in receipt of signal x^* has a uniform belief over the proportion of withdrawals.

What is the risk that the bank fails when it only has recourse to unsecured debt? If the return at date 2 is θ_2, let θ_1 and θ_0 denote the date-2 returns expected at dates 1 and 0, respectively. And let

$$\theta_\tau = \theta_{\tau-1} + \sigma_\tau \varepsilon_\tau, \tau = 1,2, \tag{11}$$

where $\varepsilon_\tau \sim \phi_\tau$, ϕ_τ denotes the densities (with associated cumulative density functions, Φ_τ, assumed to be normal) of the zero mean shocks, ε_τ, that are independent across dates. Thus, at the interim period, with date-2 returns expected to be θ_1, solvency risk is:

$$N_1(\theta_1) = \Phi_2\left(\frac{\theta^{**} - \theta_1}{\sigma_2}\right). \tag{12}$$

Since the date-1 expectation of returns is a random variable from the perspective of date 0, the insolvency risk at date 0 is:

$$N_0 = \int_{-\infty}^{\infty} \Phi_2\left(\frac{\theta^{**} - \theta_1}{\sigma_2}\right) \frac{1}{\sigma_1} \phi_1\left(\frac{\theta_1 - \theta_0}{\sigma_1}\right) d\theta_1 . \tag{13}$$

Next we define illiquidity risk as follows. At date 1, suppose creditors have an outside option r^*. If the probability of a run being unsuccessful is λ^*, and the probability of avoiding insolvency is $1 - N_1(\theta_1)$, expected date-2 returns at date 1 must be such that the creditor is indifferent between rolling over and withdrawing. Thus the critical threshold for date-1 expectations about date-2 returns below which a run occurs, θ^*, must satisfy:

$$\lambda^* r\left[1 - N_1(\theta^*)\right] = r^* . \tag{14}$$

And so interim illiquidity risk is

$$\theta^* = \theta^{**} - \sigma_2 \Phi_2^{-1}\left(1 - \frac{r^*}{r}\frac{1}{\lambda^*}\right) \tag{15}$$

or

$$\theta^* = \theta^{**} - \sigma_2 \Phi_2^{-1}\left(1 - \frac{r^*}{r}\frac{m + (1-e)}{m + \psi}\right). \tag{16}$$

Note that when $\sigma_2 > 0$, the insolvency and illiquidity points differ in general. In particular:

$$\theta^* > \theta^{**} \text{ if } -\sigma_2 \Phi_2^{-1}\left(1 - \frac{r^*}{r}\frac{1}{\lambda^*}\right) > 0 \Leftrightarrow \frac{r^*}{r}\frac{1}{\lambda^*} > \frac{1}{2} . \tag{17}$$

When this is the case, the bank is insolvent for $\theta_2 < \theta^{**}$, solvent but illiquid for $\theta_2 \in [\theta^{**}, \theta^*]$, and solvent and liquid for $\theta^* < \theta_2$.

3.2 Secured funding

We now suppose that the bank can also fund itself with long-term secured debt, S. The bank's balance sheet now becomes:

$$M + Y = D + S + E. \tag{18}$$

Solvency at the final date now requires that

$$\theta_2 Y + M - D_2 - S_2 \geq 0 , \tag{19}$$

where S_2 is the face value of secured debt in the final period. The solvency point is now:

$$\theta^{**} \equiv \frac{D_2 + S_2 - M}{Y}. \tag{20}$$

To raise secured debt, the bank pledges a fraction, $\alpha \in [0, 1]$, of risky assets to its secured creditors, 'ring-fencing' this fraction from the rest of the bank's balance sheet. We initially treat α as fixed, returning later to endogenise it. But the extent of the ring-fence can also be thought of as having been determined at date 0, effectively making the debt long term in nature.

A rise in α reduces the amount of available collateral that can be liquidated at the interim date to service unsecured withdrawals. The bank fails from a run if

$$\lambda D \geq M + \psi(1-\alpha)Y, \tag{21}$$

since $(1-\alpha)Y$ risky assets are available for liquidation in the interim period. The liquidity ratio thus becomes:

$$\lambda^* \equiv \frac{M + \psi(1-\alpha)Y}{D}. \tag{22}$$

As before, we can express the solvency point in terms of the bank's balance sheet ratios, namely

$$\theta^{**} = (r-1)m + r(1-e) - (r - r_s)s, \tag{23}$$

where $s \equiv S/Y$ is the secured debt ratio, and $r_S = S_2/S$ is the return on secured debt. Whenever $r_S < r$, i.e. secured debt is relatively cheap, a rise in the secured debt ratio improves solvency by substituting cheap secured funding for more expensive unsecured funding.[3] The liquidity ratio in the presence of secured debt is now:

$$\lambda^* = \frac{m + \psi(1-\alpha)}{m - s + (1-e)}. \tag{24}$$

The fact that secured debt requires assets to be pledged causes the bank's liquidity position to deteriorate (λ^* is decreasing in α); but since secured debt is long term, a higher secured debt ratio, s, helps to improve the bank's liquidity position by reducing reliance on 'flighty' funding (λ^* is increasing in s). Our model thus suggests that while long-term secured funding improves bank solvency if secured debt is relatively cheap, the effects on liquidity risk are more ambiguous. While the amount of collateral that is available to service interim withdrawals by unsecured creditors is lowered, the bank's *ex ante* vulnerability to such runs is reduced, since flighty funds are replaced with stable funding.

Note further that:

$$\frac{\partial \lambda^*}{\partial \psi} = \frac{1-\alpha}{m - s + (1-e)}. \tag{25}$$

Compare this to Equation (10). The sensitivity of the liquidity ratio to risky asset values increases in the presence of long-term secured debt only when $\alpha < 1 - \frac{m - s + (1-e)}{m + (1-e)}$.

The bank becomes more exposed to interim liquidity risk in the presence of long-term secured debt than in the case where it funds using short-term unsecured debt alone and the fraction

3 The exogenous wedge $r - r_S > 0$ entails a failure of the Modigliani-Miller theorem; the returns on secured and unsecured debt do not adjust to reflect their relative riskiness. This may reflect, for example, segmentation between the buyers of the two types of claim.

of pledged assets is small. To see this, consider the case $\alpha=1$. In this instance, all risky assets are ring-fenced and pledged to secured creditors. So their collateral value is irrelevant from the point of view of unsecured creditors. Liquidity risk rises in a levels sense since $\lambda^*|_{\alpha=1} < \lambda^*|_{\alpha=0}$. But because risky assets can never be liquidated to meet withdrawals by unsecured creditors, their liquidity value does not matter for liquidity risk – λ^* becomes independent of ψ and a potential source of cyclicality is removed.

3.3 Endogenous asset encumbrance

We now allow secured debt to have a more short-term flavour. At the interim date, the probability of an unsecured bank run being successful is $1-\lambda^*$. Short-term secured creditors are able to 'dash for collateral' and demand that collateral be posted at the interim date in order to cover themselves against the possibility that the bank may suffer a run and enter resolution. As such, they demand collateral αY, which can be used to obtain cash $\psi\alpha Y$. In the event of a run, expected losses are covered by the liquidation value of pledged assets, that is $\psi\alpha Y = (1-\lambda^*)S$. It follows, therefore, that the fraction of pledged assets needed to support an *ex ante* debt ratio of s for a given resale value of collateral ψ is:

$$\alpha = \frac{1-\lambda^*}{\psi} s\,. \tag{26}$$

In describing the bank's interim liquidity risk, there are now two equations, Equations (24) and (26), in two unknowns λ^* and α. From Equation (24), a reduction in ψ reduces λ^*, making a run more likely; and from Equation (26), a reduction in ψ increases α, which further reduces λ^*. Secured debtholders thus endogenously demand that more collateral is posted as interim liquidity declines, compounding the effects of declining asset liquidity on the probability of a bank run by unsecured creditors.

Solving Equations (24) and (26) yields

$$\lambda^* = \frac{m+\psi-s}{m-2s+(1-e)} \tag{27}$$

and

$$\alpha^* = \frac{s}{\psi} \times \frac{(1-e)-s-\psi}{m-2s+(1-e)}, \tag{28}$$

which imply that

$$\frac{\partial\lambda^*}{\partial\psi} = \frac{1}{m-2s+(1-e)}. \tag{29}$$

Comparing Equations (29) and (25), we see that when creditors can scramble for collateral, the probability of a run becoming successful becomes much more sensitive to collateral values than would otherwise be the case. And, compared to the model with unsecured creditors only, Equation (10), the bank's liquidity risk is much more sensitive to collateral values. This is because, with secured debt, the interim resources available to unsecured creditors vary with pledged collateral, and the pledged collateral – in turn – varies with its resale value. Our framework thus highlights the possibility that short-term secured debt can exacerbate the sensitivity of liquidity risk to collateral values.

Finally, the analysis can be extended to allow for the possibility that secured creditors may also seek to guard themselves against solvency risk. Recall that the probability of the bank being insolvent, when viewed from a date-1 perspective, is $N_1(\theta_1)=\Phi_2\left(\frac{\theta^{**}-\theta_1}{\sigma_2}\right)$. So if collateral is demanded in the interim period to cover against both the possibility of a run and insolvency, $\alpha\psi Y=\left[(1-\lambda)+\lambda\Phi_2\left(\frac{\theta^{**}-\theta_1}{\sigma_2}\right)\right]S$, so that:

$$\alpha=\frac{m+\psi-s}{m-\left\{1+\left[1-\Phi_2\left(\frac{\theta^{**}-\theta_1}{\sigma_2}\right)\right]\right\}s+(1-e)}. \tag{30}$$

There is now a channel through which solvency risk influences the probability of a run. When the solvency point (θ^{**}) rises, secured creditors demand more collateral. And there is less cash available at the interim date, worsening the bank's liquidity position (λ^* falls). The illiquidity threshold in this case is given by:

$$\theta^*=\theta^{**}-\sigma_2\Phi_2^{-1}\left(1-\frac{r^*}{r}\frac{m-s+(1-e)}{(m+\psi-s)+\frac{r^*}{r}s}\right). \tag{31}$$

4. Some Policy Implications

At present, while improving, gaps remain in our knowledge about the true level of asset encumbrance and the risks it poses for banks (Enhanced Disclosure Task Force 2013). There is also a paucity of data surrounding the haircuts applied to collateralised financial transactions. Improved disclosure on asset encumbrance could help improve investors' ability to price debt correctly and enable banks to maintain an appropriate balance between secured and unsecured debt. This underpins the recommendation of the Enhanced Disclosure Task Force that banks should summarise asset encumbrance information in their annual accounts. But in thinking about the form of disclosure, it should be noted that market discipline can very easily give way to excessive reaction by investors in the face of unfavourable news, particularly under conditions of market stress. Our model suggests how unsecured creditors may become more jittery when confronted with the prospect of falling collateral values and expectations that the bank's asset encumbrance might increase.

Our analysis also suggests a role for structural and cyclical macroprudential policy. In terms of structural initiatives, macroprudential regulation that seeks to restrict the share of assets encumbered and limit the types of secured funding could mitigate financial stability risks. Caps on covered bond issuance already exist in some jurisdictions (e.g. Australia, New Zealand and Canada) and range from 4 to 10 per cent of depositor assets. But in other countries, there is uncertainty surrounding asset encumbrance policy, with regulators exercising discretion in setting thresholds. Our results highlight the risks of excessive asset encumbrance, especially if banks do not have sufficient gone-concern loss-absorbing capacity.

Adjusting haircuts on secured financing either by imposing minimum requirements, or by controlling them to mitigate procyclical tendencies, could also promote the resilience of financial institutions. Time-varying liquidity requirements and time-varying risk weights on particular secured financing transactions could also serve a similar purpose. For example, by acting against the endogenous collateral requirements of short-term secured debt holders, a time-varying haircut policy could temper the sensitivity of liquidity risk to collateral values. But such a policy could face trade-offs.

To see the effect of minimum regulatory haircuts, and to capture the spirit of this form of regulation, suppose a regulator intervenes in the setting of collateral requirements for secured transactions. In particular, let the regulator mandate that haircuts on secured debt be set to *h* so as to guard against particularly severe outturns for asset prices, ψ. Denote the 'stressed' value of asset prices for the purpose of setting regulatory haircuts to be $\underline{\psi} < \psi$, such that secured transactions must occur with levels of collateralisation governed by:[4]

$$\alpha Y \min\left(\underline{\psi}, \psi\right) = (1-\lambda) S. \tag{32}$$

Analogously to Equation (26), the level of encumbrance is then:

$$\alpha = \frac{1-\lambda}{\min\left(\underline{\psi}, \psi\right)} s. \tag{33}$$

To see how this relates to the 'haircut' *h* in the secured transaction, define

$$h \equiv \frac{\alpha \psi Y - (1-\lambda) S}{\alpha \psi Y}, \tag{34}$$

that is the haircut is akin to the inverse of leverage permitted by the regulator in secured funding transactions. Using the modified value of α in Equation (33), this gives the haircut as:

$$h = 1 - \left(\frac{\min\left(\underline{\psi}, \psi\right)}{\psi} \right). \tag{35}$$

When the regulator allows secured transactions to occur at market prices, $\min\left(\underline{\psi}, \psi\right) = \psi$ and the haircut is zero. Equivalently, insisting on a positive haircut requires that secured transactions occur at implicitly more 'conservative' asset valuations than the market price whenever $\left[\underline{\psi}, \psi\right]$.

This gives rise to an interesting trade-off. From Equation (33), it is clear that the level of encumbrance, α, rises as $\underline{\psi}$ falls, for $\underline{\psi} < \psi$. In turn, this gives a liquidity threshold of:

$$\lambda^* = \frac{m + \min\left(\underline{\psi}, \psi\right) - s}{m - 2s + (1-e)}. \tag{36}$$

When the regulator reduces $\underline{\psi}$, or sets more conservative haircuts, the liquidity position of the bank deteriorates if $\underline{\psi} < \psi$ in a narrow sense because the bank is forced to pledge more collateral to secured creditors. But at the same time, there opens up a region for asset prices, $\left[\underline{\psi}, \psi\right]$, over which changes in the market value of collateral ψ have no effect on the bank's liquidity position. Asset prices could fall to some level, $\underline{\psi} + \varepsilon$, $\varepsilon > 0$, without affecting encumbrance and therefore liquidity.

In other words, haircut policy reduces the *sensitivity* of the bank's liquidity position to variation in asset prices over some range. The imposition of minimum haircut requirements can thus reduce

4 The analysis would extend to the case in which secured creditors also guard against solvency risk.

the procyclical fluctuations generated by secured debt, with any narrow increase in liquidity risk arising from greater over-collateralisation potentially being dealt with by other regulatory tools (e.g. liquidity requirements). This is one of the key underpinnings of the recent international proposals to stipulate a framework of numerical haircut floors for certain securities financing transactions (FSB 2013b). Time-varying haircut policies have also been floated as an additional possibility to combat procyclicality (Bank of England 2011). Investigating such policies in this setting is an interesting question we plan to address in future research.

Our analysis makes a number of stark modelling assumptions to highlight some of the central trade-offs entailed in collateralised borrowing. Although our results are suggestive, there is clearly considerable scope to generalise – and endogenise – several features of the framework. Embedding the model in a system context and explicitly linking the fire sale price of the collateral asset to the state of the business cycle would materially enhance our understanding of the policy alternatives. We intend to explore these themes further in future research.

References

Adrian T and HS Shin (2010), 'Liquidity and Leverage', *Journal of Financial Intermediation*, 19(3), pp 418–437.

Anand K, J Chapman and P Gai (2012), 'Covered Bonds, Core Markets, and Financial Stability', Humboldt University, Collaborative Research Center, SFB 649 Discussion Paper 2012-065.

Bank of England (2011), 'Instruments of Macroprudential Policy', Discussion Paper, December.

Bank of England (2012), '3 Medium-Term Risks to Financial Stability', in *Financial Stability Report*, 31, pp 30–46.

Brunnermeier MK and LH Pedersen (2009), 'Market Liquidity and Funding Liquidity', *The Review of Financial Studies*, 22(6), pp 2201–2238.

CGFS (Committee on the Global Financial System) (2010), *The Role of Margin Requirements and Haircuts in Procyclicality*, CGFS Papers No 36, Bank for International Settlements, Basel.

CGFS (2013), *Asset Encumbrance, Financial Reform and the Demand for Collateral Assets*, CGFS Papers No 49, Bank for International Settlements, Basel.

Enhanced Disclosure Task Force (2013), 'Progress Report on the Level and Quality of the Implementation of "Enhancing the Risk Disclosures of Banks"', 21 August.

Fransolet L and G Maraffino (2012), 'The 3y LTROs: Who and Why?', *Global Rates Weekly*, Barclays Capital, 2 March, pp 20–22

FSB (Financial Stability Board) (2013a), 'Progress and Next Steps Towards Ending "Too-Big-To-Fail" (TBTF)', Report of the Financial Stability Board to the G-20, 2 September.

FSB (2013b), 'Strengthening Oversight and Regulation of Shadow Banking: Policy Framework for Addressing Shadow Banking Risks in Securities Lending and Repos', 29 August.

Gai P, A Haldane and S Kapadia (2011), 'Complexity, Concentration and Contagion', *Journal of Monetary Economics*, 58(5), pp 453–470.

Geanakoplos J (2010), 'Solving the Present Crisis and Managing the Leverage Cycle', Federal Reserve Bank of New York *Economic Policy Review*, 16(1), pp 101–131.

Gorton G and A Metrick (2010), 'Haircuts', Federal Reserve Bank of St. Louis *Review*, 92(6), pp 507–519.

Haldane A (2012), 'Financial Arms Races', Speech at the Institute for New Economic Thinking, The Centre for International Governance Innovation, and the Mercator Research Institute on Global Commons and Climate Change Third Annual Plenary Conference 'Paradigm Lost: Rethinking Economics and Politics', Berlin, 12–15 April.

Harrison M and S Samuels (2012), 'Over Promising? Encumbrance at European Banks', *Equity Research*, Barclays Capital, 8 March.

Juks R (2012), 'Asset Encumbrance and its Relevance for Financial Stability', *Sveriges Riksbank Economic Review*, 2012(3), pp 67–89.

Krishnamurthy A (2010), 'How Debt Markets have Malfunctioned in the Crisis', *The Journal of Economic Perspectives*, 24(1), pp 3–28.

Morris S and HS Shin (2003), 'Global Games: Theory and Applications', in M Dewatripont, LP Hansen and SJ Turnovsky (eds), *Advances in Economics and Econometrics: Theory and Applications, Eighth World Congress*, Econometric Society Monographs, Cambridge University Press, Cambridge, pp 56–114.

Morris S and HS Shin (2010), 'Illiquidity Component of Credit Risk', unpublished manuscript, Princeton University, February.

Rinaldi F (2011), 'Ambiguity and Rollover Risk: A Possible Explanation for Market Freezes', unpublished manuscript, Banque de France.

Roland I and R Sowerbutts (2013), 'Driving Forces and Regulatory Treatment of Asset Encumbrance', unpublished manuscript, Bank of England.

Discussion

1. Bernd Schwaab

This is a welcome addition to the literature on the interaction between bank financing choices and financial stability. The main objective of the paper is to investigate the implications of the observed increase in collateralisation of financial transactions, such as over-the-counter (OTC) derivatives, and bank funding, such as repo funding and covered bond issuance. To this end, the paper presents a simple model of secured and unsecured bank funding to analyse the impact of increased asset encumbrance on liquidity risk, solvency risk and changes in collateral value. The main point is easily understood: collateralisation is not a panacea. Instead, increasing levels of collateralisation of bank funding may increase the procyclicality of credit provision and may even increase the probability of a sudden withdrawal of unsecured funding; also known as a bank run.

The paper by Gai, Haldane, Kapadia and Nelson distinguishes nicely the microprudential benefits from the macroprudential concerns stemming from high levels of asset encumbrance. From the perspective of a supervisor that is most concerned about the stability of a single financial institution in isolation, increased levels of secured funding are a positive: secured funding is less likely to be withdrawn during times of crisis and it is cheaper than unsecured funding. Also, the mere diversification of funding sources provides some insurance against adverse developments in any single funding market. Policymakers, however, need to weigh these microprudential benefits against the threats to the stability of the system as a whole.

In this discussion I'll focus on five comments.

First, the idea that giving preference to one group of market participants (the secured creditors) automatically discriminates against the others (the unsecured creditors), and that the latter then have an incentive to act (either by charging higher rates or withholding funding), is so intuitive and fundamental that it cannot be entirely new to the financial stability literature. And indeed, bank supervisors appeared to have learned that lesson during the Great Recession in the United States as early as 1933. In a recent paper, Calomiris *et al* (2012) describe how until March 1933, the Reconstruction Finance Corporation (RFC) rescued troubled Michigan banks mostly with secured loans, for which they required the best high-quality collateral. This de facto subordination of existing bank depositors did not eliminate funding risk and was soon abandoned. After March 1933, troubled banks were instead recapitalised with purchases of preferred stock, which only subordinated the common stockholders, and no subordination of existing unsecured debtholders occurred. Calomiris *et al* (2012) report convincing empirical evidence that troubled banks that received assistance after March 1933 were indeed more likely to survive, while no such effect is found for the banks assisted with subordinated debt before March 1933. Interestingly, the recapitalised banks increased lending, conditional on survival. The discussion and empirical evidence from Calomiris *et al* (2012) are wholly in line with the main idea of Gai *et al* that subordination leads to the withholding of unsecured funding.

Second, increased asset encumbrance due to secured funding may be problematic for reasons in addition to the ones put forward in the paper. Duffie and Skeel (2012) weigh the benefits against the costs of exceptions to automatic stays at bankruptcy for repo collateral. Currently, collateral from repo financing and OTC derivatives is usually exempt from such automatic stays. Duffie and Skeel explain that such safe harbour regulation could potentially raise social costs through five channels: lowering incentives for counterparties to monitor the firm; increasing the ability of, or incentive for, the firm to become 'too big to fail'; inefficient substitution away from more traditional forms of financing; increasing the market impact of collateral fire sales; and lowering the incentives of a distressed firm to file for bankruptcy in a timely manner. As a result, they recommend abolishing the safe harbour regulation for illiquid collateral (such as asset-backed securities) and OTC derivatives that are not centrally cleared. Upon reflection, each of these five arguments applies also in the current critique of increased asset encumbrance. In particular, the 'information economics' argument that unsecured markets provide an incentive for monitoring the borrower's activities, while secured markets do not, appears to be a first order concern.

Third, and as pointed out by the authors, there is some scope for a system context and for 'endogenising' a set of model parameters. For example, the interest rate $r = D_2/D$ that is paid on unsecured debt is currently a parameter and not an equilibrium outcome. In this regard, one may wonder whether a Modigliani-Miller funding irrelevance result (for the bank, possibly not for the system) should hold once this rate is allowed to increase with asset encumbrance. In such a setting, each bank would need to minimise its 'all-in' cost of funding.

Fourth, in the model the secured creditors stay put, while the unsecured depositors run. Repo runs, however, were a real phenomenon during the financial crisis. Conversely, the unsecured depositors often stayed put. For example, Figure 2 in Cornett *et al* (2011) reports growth in aggregate US core deposits at commercial banks after the Lehman Brothers bankruptcy. These data suggest that exploring the reverse situation, in which secured lenders withhold funding (i.e. by imposing a high haircut on repo collateral) while the core depositors stay with the bank, may be a worthwhile extension.

Finally, the paper adds value to the current policy discussion by reviewing several policy options in a separate section. These policy options, however, are either rather blunt (e.g. the fixed cap on asset encumbrance at x per cent of deposits) or involve a substantial amount of expert judgement (setting time-varying liquidity requirements, risk weights or caps). Perotti (2010) discusses some additional and interesting policy options. These are (i) a central repository, similar to a credit registry, for additional disclosure; (ii) a Pigou tax/levy, to make secured lenders pay for the 'super-priority' associated with safe harbour claims; and (iii) the idea of a cap-and-trade model for total asset encumbrance (Stein 2012). In particular, the idea of a central repository holds intuitive economic appeal.

In conclusion, it has been a pleasure to discuss this interesting and accessible paper on a relevant topic.

References

Calomiris CW, JR Mason, M Weidenmier and K Bobroff (2012), 'The Effects of Reconstruction Finance Corporation Assistance on Michigan's Bank Survival in the 1930s', NBER Working Paper No 18427.

Cornett MM, JJ McNutt, PE Strahan and H Tehranian (2011), 'Liquidity Risk Management and Credit Supply in the Financial Crisis', *Journal of Financial Economics*, 101(2), pp 297–312.

Duffie D and D Skeel (2012), 'A Dialogue on the Costs and Benefits of Automatic Stays for Derivatives and Repurchase Agreements', University of Pennsylvania, Institute for Law and Economics Research Paper No 12-2.

Perotti E (2010), 'Systemic Liquidity Risk and Bankruptcy Exceptions', CEPR Policy Insight No 52.

Stein JC (2012), 'Monetary Policy as Financial Stability Regulation', *The Quarterly Journal of Economics*, 127(1), pp 57–95.

2. General Discussion

The discussion of the paper presented by Prasanna Gai largely focused on a range of potential ways to address the issues raised in the paper around encumbrance, and additional features to consider in broadening the model.

One participant suggested that the financial stability issues associated with the increase in the riskiness of unsecured debt as the level of collateralisation rose could be alleviated through greater use of unsecured debt instruments such as contingent convertible bonds (CoCos), which converted to equity when equity fell below a certain threshold. Since this writedown occurred while the institution was a going concern, and bolstered the liquidity position, the value of CoCo debt was independent of the level of encumbrance. It was suggested that, combined with greater use of deposit funding, which had proven to be less flighty during the financial crisis than might have been expected, more use of CoCos should mean that collateral encumbrance became less of a constraint on banks. Professor Gai suggested that a more detailed model could allow for multiple funding forms with endogenous rates of return, adding that he suspected CoCo bonds would tend to be an expensive option to utilise.

Relatedly, another participant noted that changes to the composition of funding outside the euro area since the financial crisis had been characterised by substitution towards deposit funding from unsecured retail sources, rather than an increase in asset encumbrance. They followed this with the interesting conjecture that implicit government guarantees of retail deposits were subsidising this shift in sources of funding for banks in a distortionary manner, suggesting that deposit insurance needed to be more sensitive to the funding structure.

Another participant took a broader view of which bank funding structures were likely to promote stability, suggesting that the optimal structure was endogenous to the type of stresses being faced and that encumbrance was not always the binding concern. As an example, the participant raised the Cypriot experience, where depositors had absorbed losses because the largely unencumbered, deposit-funded bank balance sheets lacked an unsecured debt component that could be subject to a haircut. This was contrasted with Greece, where senior unsecured debtholders were able to be haircut.

The importance of central bank liquidity policy in determining optimal funding structures was also raised. In particular, it was noted that increasing encumbrance reduced the collateral that could be presented to central banks to secure emergency liquidity provision. Furthermore, it was noted that the degree of encumbrance was irrelevant for LCR purposes. Professor Gai agreed this was an important point; a richer model with portfolio choice would allow some consideration of how different funding structures arose.

Another participant enquired about whether the model had anything to say about the optimal level of encumbrance. It was noted that the available evidence suggested that credit ratings increased with the proportion of covered bonds encumbered until approximately 15 per cent, while New Zealand regulatory authorities had set a maximum limit of 10 per cent encumbrance for covered bonds. Another participant asked if determination of this optimal level of encumbrance needed to consider the nature of the creditors providing funding and the potential benefits they received from providing funding on a secured basis. In particular, the participant suggested that long-term secured funding mitigated insolvency risk for the creditor. Professor Gai responded that his model sidestepped the question of optimal encumbrance, but indicated that this issue could also be addressed in a richer model with portfolio choice. He suggested that considering creditors would be more difficult because this involved analysing multiple global games that were played out contemporaneously.

Haircut policies were discussed by a number of participants. One participant suggested that it was maximum, rather than minimum, haircuts that were needed, because it was the increase in haircuts during stress periods that could lead to fire sales of unencumbered collateral and the adverse feedback loop discussed in earlier sessions. Another participant responded that both minimum and maximum haircuts were already in place where possible, and that remaining cases were best left alone because these provided a good mark-to-market pricing mechanism. Professor Gai said he was sympathetic to this latter view, and would personally err towards caps on encumbrance rather than on haircuts, but noted that his co-authors might have a different view. He concluded by stating that these two regimes would be likely to have substantially different implications.

Policy Panel

1. Kevin Nixon

By way of introduction, I should mention a little bit about the Institute for International Finance (IIF), to give you an idea of who I am representing. We have about 470 members across 70 countries. Banks make up about 55 per cent of our membership; much of our membership is made up of buy-side firms, including insurance companies. Many of our members are in emerging market countries. So we are not just an association of large banks. Having said that, all the major global banks are members of the IIF and are represented on our board.

I will look at wrapping up the last couple of days of discussions from an industry perspective and also throw out some extra thoughts on the impact of regulation. I will start with a couple of high level points, and then give some specific examples.

I think it is clear from what happened during the global financial crisis that reform was necessary. But while it is important that we try to address what was bad about the financial system before the crisis, we don't want to get rid of what is good about the financial system.

Another important point that sometimes gets lost in the public commentary is that regulation, almost by definition, is a barrier to entry. Barriers to entry increase inefficiency in the market, which means that when introducing regulation you have to balance this loss of efficiency against the goal of the reform agenda, which is to increase the resilience of the system. Importantly, institutions will still fail, so we need to find a way of dealing with that in a way that does not rely on taxpayer funding or have systemic impacts. There was a bit of talk about failed regimes earlier and I want to touch on that later.

Another important aspect of the debate around financial regulatory change is that we are not currently in the desired steady state and the transition to that steady state matters as much as the desired steady state itself. In particular, there will be implications for the allocation of resources and credit flows, both in the steady state and in the interim.

Over the past couple of days, we've spoken about the impact of individual reforms, and it's clear from the discussions that have taken place that there's a real sense that we're embarking on the reforms without really knowing what the impact will be either at the individual or aggregate level. The aggregate effect is not just going to be the accumulation of individual effects but will also be driven by the interaction between individual elements. I think we'll be seeing a lot of concerns and calls for further understanding of this nature in the future.

Another common theme in our discussion has been transparency. It was mentioned in the context of what's happening in the repo and international derivatives markets, where there has been a focus on transparency around data such as trade volume. But even getting trade repositories in place to achieve this level of transparency is proving extremely challenging. Another aspect of transparency that has been discussed is the transparency of the banking system to investors. Two aspects are particularly important: (1) transparency about what bank balance sheets really look like, for example, the level of encumbrance and risk-weighted assets on bank balance sheets; and (2) transparency about how reforms, which are still being developed and have not yet been fully implemented, will affect bank business models. Not knowing what the final business model will look like, and what the implications might be for credit creation more broadly, means there is a great deal of uncertainty about which banks investors want to invest in.

Now I will turn to more specific reforms. There has been a lot said about collateral over the past few days. I think there are justified concerns about how all the forces on collateral markets are going to work. There are at least two new sources of demand coming from regulation. The first is a desire to increase collateralisation through over-the-counter (OTC) reforms. Returning to a point made earlier, when it comes to OTC derivative markets, moving from a bilateral to a centrally cleared environment reduces the amount of collateral required if participants are paying initial margin in both environments. However, initial margin is not currently standard in bilateral clearing environments, so a big increase in collateral is required to go from the current environment to one where all trades are centrally cleared and initial margin is paid. So while there are relative benefits within the hierarchy of potential approaches to clearing of derivatives and varying levels of demand for collateral, they're all worse than where we are now in terms of the amount of collateral that banks need to hold. That has been spoken about a lot so I'll leave that aside. Then you have repo reforms, perhaps even the central clearing of repos, that would entail all the issues we have with the central clearing of derivatives, proposals on how to reform the shadow banking system and minimum haircuts.

The second new source of demand comes from the need to increase the holdings of high-quality liquid assets on bank balance sheets. In addition to all this, there are the leverage ratio proposals. If the leverage ratio comes to have a more prominent place in bank regulation than risk- weighted assets, it will have the effect of penalising very short-dated holdings of very highly liquid, highly rated securities as well as market making in repos.

Aside from making the system more resilient, we need to make sure that resolution works; in other words ending 'too big to fail'. This has two components. One is ensuring that taxpayers are not on the hook for bank failures and that creditors bear the losses that bankruptcy law says they should. But more than that, it's about doing it in a way that ensures preservation of systemic stability, which means that any bank should be able to fail without systemic impacts. So there's a lot more to resolution than just bail-in, although this is a part of it.

In terms of funding markets, the current direction of the bail-in debate is going to have two high level effects. One is that because of the desire to protect depositors, which has been highlighted by recent events in Cyprus, there has been a move towards having a minimum layer of securities contractually subject to bail-in. There will be a regulatory mandate in place in every major jurisdiction that will require banks to issue a layer of (potentially contractually) bail-in-able bonds. What their price should be is unknown, but the market will determine this. These developments will require changes to bank balance sheets. For some banks, the changes will be very small. But for the large number of banks that are deposit funded, which has been promoted as a good business model based on regulatory changes such as the Liquidity Coverage Ratio (LCR), they will need to issue significant volumes of this bail-in-able debt. The impact on markets is clearly that there will be some crowding out of other debt issuance that would otherwise have been expected. There's a question mark over what this does to the bank's balance sheet and business model.

Within the bail-in debate there is also a hierarchy of what preference is given to which creditors. The current proposal in Europe, for example, is that all natural persons will receive preference for their deposits. That is not to say that there won't be a haircut, but rather that they will receive haircuts after everyone else; that is, they will be super-senior creditors. The Europeans are considering carving out small business deposits as well, and the moment that you start carving out more and more creditors, it becomes similar to the secured funding issue presented by Prasanna Gai (in this volume). In other words, more of the failure falls on a smaller group of creditors. The first group of creditors to absorb losses are hybrid investors who are subordinate to the debtholders, and this is well understood. Then there is a layer of bail-in-able securities. But then the question arises as to how this will change behaviour and, more specifically, whether some classes of investors are more likely to run.

These are all areas where policymakers could probably spend more time considering some of the developments and implications we have talked about over the past day and a half, before finalising these policy changes. But unfortunately, given what happened in 2007–2009, the drive to deliver significant policy changes are the imperative.

There is still a large amount of work to do on understanding the implications of Basel III. For example, there are important questions around the calibration and phasing in of the net stable funding ratio (NSFR). The NSFR by definition reduces the amount of maturity transformation that the banking system will do. Of course, maturity transformation is the mainstay of what the banking sector has been doing for several hundred years. Again, in a purely efficient market you may not get the outcomes you want in terms of stability, so there may be a case for policy intervention. But I think this is the area where we need to do a lot of work to understand the impact and trade-offs associated with introducing regulatory change.

On the transparency side, another element of the Basel III framework that doesn't get a lot of attention in commentary or debate is LCR disclosure. This is very much a two-edged sword. A lot of stakeholders and a lot of commentators want to see enhanced LCR disclosure; they want to know exactly what the liquidity position of a bank is at any given time. However, there is a real risk in doing that. If a bank is announcing weekly LCR statistics, and announces this week that its LCR is 109 per cent, 108 per cent the next week, and 107 per cent the week after, the following week it will be going to the central bank looking for lender of last resort as the likelihood of a run will be high. There's a real sense that you need to calibrate not just the reforms themselves, but also how to communicate the positions associated with those reforms. Again, these transmission mechanisms and response functions need to be thought through very carefully.

The leverage ratio is another example. If the leverage ratio becomes a more binding constraint, then you will start requiring capital against any asset, regardless of its riskiness. This clearly provides incentives to stay away from holding high-quality liquid assets, participating in repo markets, trading short-dated government bonds and things like that. Some of that business may move to other sectors, but there is a transition element as well.

On OTC reforms, it is also worth mentioning that there is a bias towards standardised derivatives, which go through central clearing and have a lower capital requirement as a result. The initial margin on non-standardised derivatives that are not centrally cleared will be much higher. This creates a number of issues for end users because they do not have the same access to private interest rate swap markets for hedging portfolio risk as banks, fund managers and debt management offices. For end users that have to use hedge accounting, dates and coupons must be matched exactly to exposures. If those non-standardised derivatives are made more expensive, we are yet to see what that means for things like asset swap markets and cross-border financing.

We are hearing from our emerging market members that the impact on cross-border financing, a lot of which requires cross-currency swaps, is already being felt through constraints on infrastructure finance. Emerging markets need to draw in capital from outside their jurisdiction, and they are concerned about their ability to continue to do that if cross-currency swaps used for hedging become prohibitively expensive. This problem is particularly acute at the moment as European banks are moving back towards their home jurisdictions, and so we are seeing a drop in syndicated lending.

With all of these things, it's not that the reforms aren't necessary, because they clearly are; we do need to manage counterparty risk on OTC derivatives, we do need to make sure banks have adequate liquidity resources, and we do need to make sure banks can fail without systemic impacts. However, we also need to do more work on understanding what the transmission mechanisms involved are to guide how we change the financial system. That has been one of the main topics of discussion at this conference.

There are a range of things I could talk about in more detail, but the key point I'd like to make is that the financial system will be very different from what it is now. In general, as discussed over the past day and a half, we don't really fully understand what the impact of the new system will be. I think we have some sensible clues to watch out for, but I also think we need to monitor the new system very closely. So I think the regulations as they are developed and finalised should be seen as a work in progress, and calibrated as we understand more about the impact they are having on the system and get more data about what's going on as well. Not only do we need data on the structure of the system, but we need to accumulate data on the impact of the reforms as they evolve.

2. Richard Portes

The role of this panel is to intermediate between authors and discussants and the group as a whole. As many maintain that all our problems since 2007 result from failures of intermediation, this is a difficult assignment. I shall focus on issues where more research is needed – that is my role as an academic.

The conference has gone beyond 'Liquidity and Funding Markets' to broader regulatory issues, and my remarks will do so as well. I start with some general matters.

A complication that came up frequently in our discussions is endogeneity. For example, Piti Disyatat stressed the endogeneity of capital flows with respect to the demand for intermediation. Again, the VIX is sometimes taken as an exogenous determinant of capital market flows, but of course it is endogenous to any risks or volatility generated by these flows. In another example, some conjecture that excess demand for 'safe assets' led to the creation of private-label assets that were supposedly safe, as certified by the ratings agencies. But it is not obvious that German Landesbanken were looking for 'safe assets' when they bought large amounts of US structured securities – rather, they were looking for yield and found it convenient (though not necessary) that the ratings agencies provided comfort.

We have had much discussion of partial equilibrium versus general equilibrium models – as economists do. I fear we have not made much progress here. I myself am often content with partial equilibrium if I can reasonably believe that the feedbacks are second-order. I think we are sufficiently aware of these problems not to ignore them. Building general equilibrium models of the financial system is a daunting task.

I would flag for research the cyclicality of variables that were central to our discussions: haircuts, margin requirements, the value of collateral and its velocity of circulation. We are clear that these are important questions, but we are very unclear on the empirical evidence.

There are major data puzzles that have arisen. I was struck by Grahame Johnson's figure that showed 'activity-based' shadow banking peaking in 2007 at a level only slightly higher than it was over 1999 to 2003. This runs counter to the conventional wisdom of an explosion of shadow banking activity during the period leading up to the crisis. The lessons: a lot depends on the definition of shadow banking (no surprise, but still …); and here, as elsewhere, our data are very poor. Prasanna Gai's paper provokes me to ask the regulators whether they have any reliable data on asset encumbrance and haircuts – if not, why not?

Political economy issues loom large for me, even in a conference with a title that sounds rather technical. Grahame Johnson pointed out a conflict between the desire of regulators for more collateralisation with safe assets; fiscal policies oriented towards reducing issuance of government debt, the ultimate safe asset; and monetary policy trying to induce private sector portfolio substitution towards risky assets. These are not just technocratic desiderata. Also political is the pushback of the big banks against moving OTC derivatives trading to exchanges or at least CCPs – the banks have resisted, with fierce and hugely well-funded lobbying, because they make so much money from opacity in these instruments and transactions. Trading is dominated by an oligopolistic handful, and they have been very successful with delaying actions. I can recall a well-informed academic who works in this area telling me in the middle of 2009 that all credit default swaps (CDS) contracts would go through CCPs by the end of that year. Well-informed but naïve.

We have heard several references to the concerns of banks about the stigma associated with seeking help. But the US experience with the Troubled Asset Relief Program (TARP) suggests that the regulators can neutralise this resistance if they are willing simply to override the bank lobby and treat it as an undifferentiated collective (partly because it is hard to tell which banks are the most fragile). Some may need help, all must accept it. A final pervasive political economy issue is cross-border jurisdictional conflicts. These go beyond turf battles to high-stakes confrontations or – even worse, perhaps – simple unilateral actions that disregard common interests. Repeated conflicting actions from the United States and the European Union do not arise from insufficient consultation or lack of information, but rather a search for perceived competitive advantage or an unwillingness to put sensible compromises to hostile domestic constituencies. On the global scene, we have heard from Alex Heath about the concerns of 'peripheral' countries that the regulators will constrain global banks in ways that hurt their interests relative to those of the 'core' countries.

This brings me to regulation. There are many puzzles arising from the reluctance of regulators to intervene. For example, one might think that if the regulators were concerned about excess demand for collateral, they would put a much higher priority on CCPs and netting, which reduces the demand for collateral. A related issue is the sheer size of CDS markets and the long chains of transactions that exaggerate the problem, making gross exposure so much greater than net exposure. This matters greatly – one reason cited for the delay in Greek debt restructuring was the concern that it would trigger payouts on huge amounts of outstanding CDS contracts (US$80 billion gross) with unforeseeable consequences. Of course, when it finally came to that, there was no difficulty in dealing with the US$4–5 billion of net exposures. Why shouldn't the regulators simply constrain the volume of these transactions, in any case?

The correct answer to that question is pervasive, intensive lobbying that can spend a million here and there when the stakes are many billions of profits. The lobbyists present this, however, as promoting the general good: the banks – and some academics – say that regulation creates barriers to entry (Kevin Nixon just made this point); that it should not restrict what appear to be Pareto-improving transactions among consenting agents; and that financial innovation and moves towards more complete markets must bring advantages. Such arguments are often very partial equilibrium indeed, ignoring systemic implications, second-best considerations, and egregious cases of concealing or misrepresenting information (e.g. Fabrice Tourré and the London Whale).

We spent some time on collateral and safe assets. Prasanna Gai's paper should make us ask in each application of collateral requirements, what is the balance between safety and the disincentive to monitoring (moral hazard) that high collateralisation can induce in asset holders? I did not hear any convincing set of principles to guide regulators in drawing the line. I will not go further than my remarks during the relevant sessions on why I believe the 'safe asset meme' is highly misleading, as I have made those arguments in more detail elsewhere. No asset is or ever has been truly 'safe' – there is a continuum. Only our models require pure safe assets – the financial system can get along very well dealing along that continuum, and the system can generate a range of benchmarks should the need arise. Nor is there a generalised shortage: both supply and demand adjust endogenously to eliminate shortages should they appear at a global level, although there may be some local persistent disequilibria.

One issue on which we can probably agree is that central bank policies regarding acceptable collateral can be harmful. Coming from Europe, I have in mind the incoherent European Central Bank policies that have created instability. They have shifted risk onto national central bank balance sheets; and they have maintained the misplaced emphasis on ratings as a determinant of haircuts, with the consequent risk of vicious circles both for sovereigns and for domestic banks that hold large quantities of sovereign debt. The issue of collateral standards deserves much more attention.

Finally, I want to bring in a longer-term perspective that we seem to have lost. We tend to think of the past couple of decades, in which financial systems and 'financialisation' have expanded at an unprecedented rate, as the 'new normal'. So when the crisis hit, we looked for remedies within that framework. This may be partly because economic history has disappeared from graduate program teaching in most of the top economics departments. We cite the Chair of the US Federal Reserve Board and a few others as bringing to bear the lessons of the Great Depression. But all too many never learned them. Moreover, economic history progressed greatly when it moved beyond recounting and interpreting events to analysing counterfactuals, and we seem to have lost this lesson. Relevant to the topic of this conference, we should be asking, for example: what if there were no interbank market (after all, the unsecured interbank market has disappeared)? What if there were no money market funds? What if there were no commonly agreed benchmark securities? Indeed, what if US net government debt issuance were to go to zero, as seemed possible as we moved from the Clinton surpluses into the George W Bush presidency? Research should go forward, placing liquidity and funding markets in this broader context.

3. Jean-Pierre Danthine

The Impact of the LCR on the Swiss Repo Market

Franklin Allen's survey for this conference and much of the discussion of the past couple of days have highlighted how fragmented our knowledge of funding and liquidity markets remains, and how many open questions we are thus facing when we attempt to estimate the impact that regulation could have on these markets. At an intellectual level we may be tempted to proceed sequentially and wait until we have satisfactory answers to the main questions before advancing with new regulation. Impatience at the pace of progress on the regulatory front is also understandable, however. It is more than five years since the start of the crisis and, while many steps have already been taken, much remains to be done. The questioning is particularly acute when it comes to the Liquidity Coverage Ratio (LCR), which is the element of regulation I would like to focus on in this contribution. Specifically, I will discuss the key challenges that arise with the implementation of the LCR in Switzerland, and in particular its impact on the Swiss repo market. I will then suggest elements of a potential solution for dealing with these challenges and ensuring that implementation of the LCR does not – paradoxically – decrease the efficiency of the main market source of liquidity.

Liquidity regulation, a means to ensure that central banks are only lenders of last resort

First of all, a question of principle needs to be dealt with. If central banks can provide unlimited liquidity, free of cost, can it be socially optimal to impose costly liquidity rules on market participants? The response to this frequently raised objection lies in the observation that emergency liquidity assistance (ELA) by central banks is in fact costly in at least three different ways.

First, there is a moral hazard issue. Banks that can rely on central banks' unrestricted liquidity provision at any time have no incentive to manage their liquidity risks and hold adequate liquidity buffers. This may lead to excessive liquidity risk-taking.

Second, it is difficult to differentiate liquidity problems from solvency problems. Providing liquidity to an insolvent institution can have very expensive consequences for the central bank.

Third, the provision of ELA to a financial institution may give rise to liquidity problems at other institutions. Contagion of this kind can arise as a result of the opacity and complexity of large financial institutions, making it very difficult for market participants to distinguish between idiosyncratic and systemic liquidity shocks. This may make other institutions with profiles similar to the institution receiving liquidity support suspect in the eyes of the market and may rationalise destabilising behaviour by their counterparties.

For these reasons, there is no doubt in my mind that it is right to insist that banks are capable of standing on their own in the event of significant liquidity shocks. A central bank should be no more than a lender of *last* resort. This principle in itself does not, however, suffice to determine the optimal design of liquidity regulation.

With respect to the latter, a better understanding of the impact of the introduction of the LCR on funding markets and liquidity is crucial. Here, Switzerland may serve as an interesting case study for three reasons. First, a Swiss liquidity regime similar to the LCR has been in place since mid 2010 for the two big banks (UBS and Credit Suisse). Hence, it may be possible to draw preliminary conclusions regarding the impact of such a liquidity regime. Second, under normal monetary conditions, Switzerland has a shortage of high-quality liquid assets in domestic currency (CHF HQLA) as defined in the LCR, due to its large financial sector and comparatively low level of public debt. Third, introducing the LCR is likely to have an impact on the characteristics of the Swiss repo market because of its specific features. On the one hand, Swiss National Bank (SNB) open market operations and interbank repo transactions are conducted on the same repo trading platform against the same collateral basket; on the other, the share of cross-currency repos is large.

Experience with the Swiss liquidity regime for large banks

In Switzerland, a liquidity regime for systemically important banks has been in force since mid 2010. The Swiss liquidity regime is similar to the Basel III LCR. Both are stress-based metrics. The stress scenario underlying the Swiss liquidity regime is more severe, though, which leads to generally more conservative outflow rates compared with the LCR. Moreover, the definition of the liquidity buffer is broader and less focused on government bonds. In particular, there is no differentiation between currencies in the Swiss liquidity regime; hence, the liquidity buffer contains a substantial share of HQLA in foreign currencies.

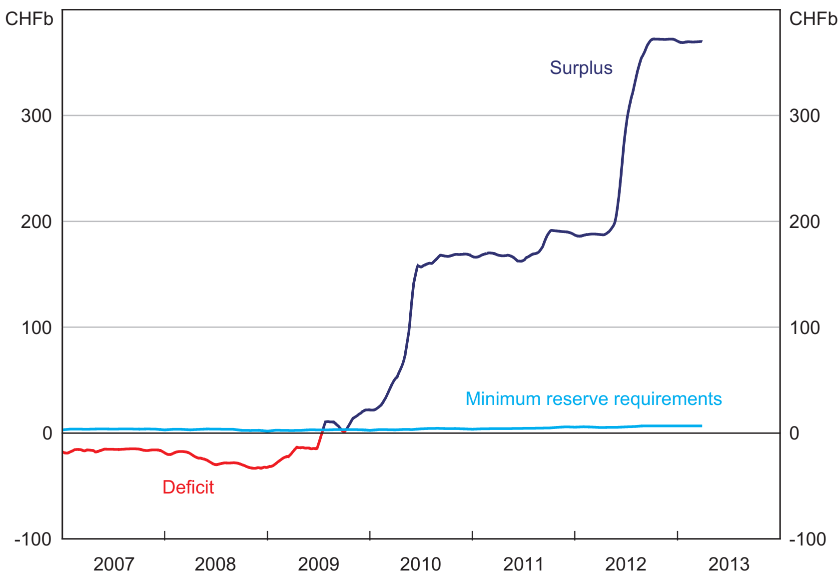
Unfortunately, it has not yet been possible to draw any initial lessons on the potential impact of the Swiss liquidity regime on funding markets and the banks' liquidity positions. This is because the current situation is characterised by very low interest rates and an overabundance of liquidity in the system.[1] As a consequence, the holding cost of HQLA is insignificant and the liquidity constraints imposed by the liquidity regime are essentially non-binding. The Swiss liquidity regime has, up to now, had no significant effect on either the behaviour of the two big banks or on funding markets, liquidity and credit allocation. But this is clearly not a reliable lesson for the more normal circumstances that will prevail again at some point in the future.

1 The exchange rate floor to the euro introduced in September 2011 is an exceptional monetary policy measure taken by the SNB against the background of deflationary risks and excessive appreciation pressures on the Swiss franc observed since 2008. It has led to significant foreign currency purchases by the SNB.

Implementation challenge 1: Shortage of domestic currency HQLA

Let me now turn to the challenges of LCR implementation: first, the issue of a shortage of local currency HQLA. In this regard, Switzerland has been, until recently, a typical example of a jurisdiction that would need to have recourse to specific implementation options envisaged within the LCR framework to deal with such a shortage. However, as a consequence of the SNB's monetary policy at the zero lower bound and the ensuing massive injection of liquidity into the system during the crisis, Switzerland has moved from the traditional regime of liquidity deficit to one of a very large liquidity surplus (Figure 1).[2] This has reduced the shortage of CHF HQLA. This situation, however, should not be interpreted as a new steady state. If, at some point in time, monetary policy considerations induce the SNB to reduce the liquidity surplus, the universe of CHF HQLA will be affected again. In the case of a temporary reduction, the choice of instrument (e.g. reverse repos or SNB Bills) will determine whether or not a reduction of CHF HQLA results. In the case of a permanent reduction, a corresponding decrease of CHF HQLA will occur, by definition. However, the impact of monetary policy decisions on the universe of HQLA should not influence the choice of the appropriate balance sheet size for the SNB, or the future monetary policy framework. Consequently, the structural shortage of CHF HQLA should be taken into account when implementing the LCR.

Figure 1: Structural Liquidity Position of the Banking System versus SNB
30-day moving average



Note: Deficit/surplus relative to minimum reserve requirements
Source: Swiss National Bank

2 A structural liquidity position of the banking system is defined as net claims on, or liabilities towards, the central bank. If the banking system has net liabilities to (net claims on) the central bank, it is in a structural liquidity deficit (surplus).

Implementation challenge 2: Impact on Swiss franc repo market

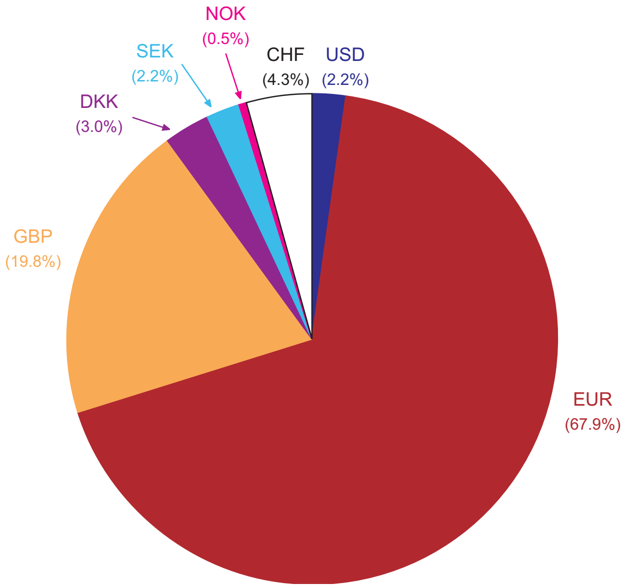
The potential impact of the LCR on the functioning of repo markets is the second key challenge. Whether or not the LCR poses a problem in this regard crucially depends on country-specific repo market characteristics, such as the collateral standard and haircut practices. In particular, in repo markets where liquidity is primarily provided against domestic government bonds, the effects of introducing the LCR will be small or even non-existent, as both the cash and the security are considered to be of the highest quality (Level 1) in the LCR rulebook. This will, however, not hold true for repo transactions against Level 2 assets or non-HQLA. In the latter case, different haircuts apply. Typically, when one compares the LCR haircut schedule with haircut policies applied by central banks and on international repo markets, one finds that market haircuts tend to be higher for Level 1 assets and lower for Level 2 assets relative to the LCR haircuts. This is partially explained by the fact that the haircuts applied in the LCR are computed to account for price changes at a 30-day horizon in stress situations. By contrast, haircuts applied by market participants correspond to the price changes that can be expected in normal times over shorter horizons.

The difference between LCR and repo market practice with respect to haircuts and collateral standard is particularly evident in the case of the Swiss automated repo market, which features the following characteristics. First, it allows for twice-daily margin calls. Second, close to 99 per cent of the transactions in the Swiss repo market, whether interbank or with the central bank, are today – and were in the years preceding the crisis – effected against SNB-eligible collateral (the SNB general collateral (GC) basket). The vast majority of these transactions are not concluded against a specific security from this basket but against the basket itself.[3] Third, the securities in the SNB GC basket are predominantly – up to 96 per cent – denominated in non-CHF currencies (Figure 2).[4] Finally, repo transactions are neutral with respect to the existing Swiss liquidity rules, as the latter rely to a very large extent on non-Swiss franc-denominated assets as well.

3 These GC repo transactions primarily support daily liquidity management. The securities transferred serve as collateral and play a subordinate role, provided certain quality criteria are met.

4 Securities denominated in foreign currency must satisfy stringent quality requirements with respect to credit rating (minimum rating requirement AA-/Aa3) and liquidity properties (minimum issuance volume of at least CHF1 billion counter value).

Figure 2: SNB Repo-eligible Assets by Currency
As at 19 July 2013



Source: Swiss National Bank

Given the frequent margining and the high quality of the assets included in the SNB GC basket, the Swiss repo market has historically functioned with a zero haircut. The LCR rules, however, impose haircuts or restrictions on the use of most of the securities included in the SNB GC basket; in particular, on foreign currency-denominated assets. The implication of this haircut difference is that repo transactions – whether with the central bank or in the interbank market – will not necessarily be LCR-neutral in the future. In other words, any repo transaction against non-CHF government securities will have an impact on the LCR of the institutions involved. As a consequence, not only cash management objectives but also LCR considerations will enter into the decision to conduct transactions on the GC repo market. This is likely to lead to a segmentation of the repo market, as it is plausible that market participants will want to be specific as to the asset or asset class against which they want to trade. This in turn may lead to different interest rate curves, depending on the various asset classes and reflecting the difference in LCR eligibility.

Possible solutions

In order to address the identified lack of CHF HQLA and the high share of collateral denominated in foreign currency, option 2 of the Alternative Liquidity Approaches (ALA) is the natural direction in which LCR implementation in Switzerland is envisaged.[5]

5 In order to ensure a level playing field among Swiss banks, banks can apply for ALA option 3 (additional use of Level 2 assets with a higher haircut) instead of option 2 (foreign currency HQLA to cover domestic currency liquidity needs). ALA option 3 may be relevant for banks with no adequate foreign exchange risk management.

Further, to mitigate the issue of LCR non-neutrality of repo transactions, the following setting is considered: while repo transactions with a residual maturity of more than 30 days fully enter into the LCR, repos with a residual maturity below 30 days will be considered LCR-neutral as long as the collateral is part of HQLA – irrespective of whether collateral is denominated in foreign currencies or is classified as Level 2. This LCR neutrality of repo transactions should result in the activity of the repo market in maturities up to one month being largely unaffected. The LCR may, however, imply a change in the collateral standard applied by the interbank market and the SNB.

These adjustments are in the spirit of the LCR and should therefore be compliant with the new international liquidity standard. At the same time, and crucially, they ensure that the Swiss repo market retains its key function both as the main source of liquidity for the Swiss banking system and as an efficient tool for monetary policy implementation by the SNB.

4. General Discussion

A central theme of the discussion following the policy panel was the question of whether substantial progress had been made in terms of improving regulation since the onset of the financial crisis. In response to Richard Portes' statement that progress had been underwhelming, Kevin Nixon responded that liquidity management has improved, bank capital ratios were higher, and resolution arrangements for banks were largely in place. He further stated that for the most part, banks had not attempted to delay further regulation out of self-interest. He gave the example of the central clearing of interest rate swaps, where banks had adopted changes to reduce exposures and improve transparency ahead of mandates being enforced. Another participant agreed that core banks' behaviour changed around 2010 from resisting to embracing CCPs, but suggested that this coincided with their realisation that client clearing on behalf of financial institutions in the periphery was likely to be profitable.

Another theme of the discussion was the need to properly evaluate the effectiveness of the policies and financial reforms such as the LCR that were designed to promote financial stability. One participant observed that financial institutions in Australia and New Zealand had both responded to the liquidity shocks suffered during the financial crisis by increasing their core funding ratios, despite substantially different regulatory responses. In New Zealand, the conclusion from the crisis experience was that banks had been too dependent on short-term market funding and, accordingly, liquidity policies including core funding ratios and net stable funding ratios had been instituted. In contrast, market pressures from institutional investors and rating agencies seemed to have imposed a similar degree of discipline on Australian financial institutions, with specific liquidity regulation to be introduced to longer Basel III timeframes.

In general, participants agreed that the impact of liquidity regulation would remain unclear until the deleveraging process was completed and banks started using short-term funding markets more actively. Mr Nixon added that it was also unclear how different reforms would interact, particularly because it was hard to know what the new steady state would look like. Given this, he argued there was a valid case for ongoing assessment of reforms, with a willingness to make adjustments as necessary if there was evidence of unintended consequences.

Relatedly, another participant considered that the regulatory encouragement for banks seeking funding from domestic markets post-crisis could have unintended consequences for the macroeconomy. Specifically, the participant questioned how current account deficits could be safely funded if not through bank borrowing. One difficulty noted was that, while direct market lending to large companies was not problematic in itself, in stress periods where funding markets shut down, central bank liquidity provision to funding institutions would be less effective if the institutions with liquidity needs were not banks with which the central bank had an existing relationship.

Another issue that was raised in the general discussion was around the scope to develop general equilibrium models of the financial sector that could be helpful in evaluating financial regulatory policy. Noting that macroeconomic models had struggled to model the financial sector, one participant questioned if general equilibrium models were even feasible. It was noted that partial equilibrium models had demonstrated the trade-off between financial efficiency and macroeconomic stability and have accordingly aided policy setting. The best path forward for research was not clear. Professor Portes suggested that general equilibrium models were worth pursuing as they are not hampered by endogeneity issues which he noted had been raised by multiple people over the course of the conference. He added that while the latest generation of general equilibrium (DSGE) models had come in for much criticism, this modelling work was both difficult and important. He gave the example of DSGE models that attempted to integrate rich financial intermediation as frontier research worth pursuing. Network models were also generally regarded as having become a useful tool for modelling the financial sector.

The trade-off between efficiency and stability was raised by another participant, who noted that regulatory bodies had different incentives and therefore weighted these two policy objectives differently. The participant queried the extent to which a local jurisdiction could effectively achieve a position that differed from international settings, given that a lot of regulation aimed at achieving international harmonisation. Another participant responded that this was possible, but had consequences because it often required countries to operate capital controls and hold large volumes of overseas assets. Attention was then drawn to the fact that the resulting global imbalances were widely considered to have contributed to the severity of financial crises. Professor Portes provided a contrary view, suggesting that a trade-off between efficiency and stability wasn't always present. He argued that in a world with multiple equilibria, with no clear mechanism for arriving at a good or a bad steady state, regulation imposed for the purpose of stability could aid efficiency as well.

Another participant questioned the view that the central banks could repeatedly be relied on to provide unlimited liquidity, saying that this activity was ultimately conditional on the fiscal position of the state. Professor Portes argued that concerns about the significant expansion of central bank balance sheets were overdone, and there had been no negative effects as yet. He agreed that fiscal capacity was an important constraint, but suggested this was really a transparency issue. Jean-Pierre Danthine added that this fiscal constraint was particularly relevant in a world where the central bank found it difficult to determine categorically whether an institution was illiquid or insolvent before providing emergency funding.

The discussion also returned to the question of whether regulation had constrained banks' provision of liquidity. Participants specifically pointed to the fact that an LCR could limit the volume of liquidity that banks could provide and regulation on non-banks had reduced their ability to fill this gap. At the same time, there had been an increase in demand for HQLA among non-banks, with the net effect being to increase the price. One participant suggested that the relevant issue was whether supply and demand curves actually intersected at any price. Mr Nixon agreed that demand curves had shifted dramatically, but noted that this price increase could be mitigated to some extent by the ability of financial institutions to use lower-quality assets to access liquidity facilities.

On a practical note, another participant suggested that the relatively simple issue of poor transparency and lack of information was of substantial importance as this led to incomplete markets, externalities and other market failures. Despite this, the participant was sceptical about whether privacy concerns could be overcome. Mr Nixon added that regulators also wanted to promote transparency because this would give them greater access to useful data, but agreed that overcoming legal issues had proved more difficult than originally expected.

Biographies of Contributors

Franklin Allen

Franklin Allen is the Nippon Life Professor of Finance and Professor of Economics at the Wharton School of the University of Pennsylvania, where he has been on the faculty since 1980. He is currently Co-Director of the Wharton Financial Institutions Center. He was formerly Vice Dean and Director of Wharton Doctoral Programs, Executive Editor of the *Review of Financial Studies* and is currently Managing Editor of the *Review of Finance*. He is a past President of the American Finance Association, the Western Finance Association, the Society for Financial Studies and the Financial Intermediation Research Society, and a Fellow of the Econometric Society. He is currently President of the Financial Management Association. Professor Allen's main areas of interest are corporate finance, asset pricing, financial innovation, comparative financial systems and financial crises. He is a co-author with Richard Brealey and Stewart Myers of the eighth through eleventh editions of the textbook *Principles of Corporate Finance*. Professor Allen holds a PhD in Economics from Oxford University, and an MPhil in Economics and first class honours degree in Economics and Computing Studies from the University of East Anglia.

Morten L Bech

Morten Bech is a Principal Economist in the Monetary and Economics Department at the Bank for International Settlements and also serves as Secretary to the Markets Committee. He has previously worked for the Federal Reserve Bank of New York and the Danish central bank. In 2009 he was a visitor at the Monetary Affairs Division of the Federal Reserve Board in Washington DC. He has written on different issues relating to monetary policy implementation, money markets, network topology of financial markets, large-value payment systems and systemic risk. Dr Bech holds a PhD in Economics from the University of California, Santa Barbara.

Matthew Boge

Matthew Boge is the Deputy Head of Domestic Markets Department at the Reserve Bank of Australia. Previously he held a number of positions at the Reserve Bank, generally relating to financial market analysis and the Bank’s operations within those markets. He holds Bachelor Degrees in Commerce and Economics (Hons) from the University of Queensland and a Master of Applied Finance from Macquarie University.

Elena Carletti

Elena Carletti is Professor of Finance at Bocconi University. Before that she was Professor of Economics at the European University Institute, where she held a joint chair in the Economics Department and the Robert Schuman Centre for Advanced Studies. She is also a Research Fellow at the Centre for Economic Policy Research, Extramural Fellow at the Tilburg Law and

Economics Center, and a Fellow at the Center for Financial Studies at CesIfo and at the Wharton Financial Institutions Center. Her main areas of interest are financial intermediation, financial crises, financial regulation, corporate governance, industrial organisation and competition policy. She has published numerous articles in leading economic journals, and has recently co-edited a book with Franklin Allen, Jan Pieter Krahnen and Marcel Tyrell on *Liquidity and Crises*. She has worked as consultant for the Organisation for Economic Co-operation and Development and the World Bank and participates regularly in policy debates and roundtables at central banks and international organisations. Professor Carletti holds a PhD in Economics from the London School of Economics, a Doctorate in Economics from the University of Bologna and a Master in Economics from Bocconi University, Milan.

Jean-Pierre Danthine

Jean-Pierre Danthine is Vice-Chairman of the Governing Board, Swiss National Bank, and Head of Department II (Financial Stability, Cash, Finance and Risk) after heading Department III (Financial Markets, Banking Operations and Information Technology) from January 2010 to April 2012. He was previously Professor of Economics and Finance at the University of Lausanne as well as Managing Director of the Swiss Finance Institute from its foundation in 2006 to 2009, and has taught at Colombia University. He is also a Fellow of the European Economic Association. Among other things, he was previously director of the International Center for Financial Asset Management and Engineering (Lausanne and Geneva), Vice Rector of the University of Lausanne and Director of its Institute for Banking and Financial Management. He is a former member of the Executive Committee of the Center for Economic Policy Research and was an Associate Editor of the *European Economic Review*, the *Journal of Empirical Finance*, *Macroeconomic Dynamics* and the review, *Finance*. He has published extensively in macroeconomics and finance. He holds a PhD in Economics from Carnegie Mellon University and an MSc in Economics from the University of Louvain.

Kevin Davis

Kevin Davis is Professor of Finance at the University of Melbourne and, in his role as Research Director of the Australian Centre for Financial Studies, Professor of Finance at Monash University. His primary research interests are financial regulation, financial institutions and markets, financial innovation and corporate finance. He is co-author/editor of 16 books in the areas of finance, banking, monetary economics and macroeconomics and has published numerous journal articles and chapters in books. He is the Deputy Chair of Sirca, a member of the Australian Competition Tribunal, and has undertaken an extensive range of consulting assignments for financial institutions, business and government. Professor Davis is a Senior Fellow of Finsia and a Fellow of the Finance and Treasury Association. He holds a Bachelor of Economics (Hons I) from Flinders University, South Australia, and a Master of Economics from the Australian National University.

Piti Disyatat

Piti Disyatat is Director of Economic Research in the Monetary Policy Group at the Bank of Thailand. Prior to this, he worked in various areas of the Bank including forecasting and modelling, financial risk management, foreign reserve management and monetary operations. From 2007 to 2010 he served as Senior Economist in the Monetary and Economic Department at the Bank for International Settlements. He has also previously worked as an Economist at the International Monetary Fund and has served as Adjunct Faculty in the Economics Department at Chulalongkorn University and Thammasat University in Thailand. His research interests are in monetary economics, banking and international finance. He holds a PhD from Princeton University and a Bachelor of Economics with first class honours from the Australian National University.

Ippei Fujiwara

Ippei Fujiwara is Associate Professor of Macroeconomics at the Crawford School of Public Policy at the Australian National University. He is also Associate Editor of Japan and the World Economy, a Research Associate at the Globalization and Monetary Policy Institute, Federal Reserve Bank of Dallas, the Executive Director of the Australia-Japan Research Centre, and Deputy Director of the Center for Applied Macroeconomic Analysis. Previously he worked for the Bank of Japan for 18 years before joining the Crawford School of Public Policy where his research has focused on international finance, monetary economics and macroeconomics. His recent publications appear in the *Journal of International Money and Finance*; *Journal of Money, Credit and Banking*; *Journal of Economic Dynamics and Control*; and *Macroeconomic Dynamics*. He holds a DPhil in Economics from Nuffield College, University of Oxford, and a PhD in Applied Economics from Osaka University.

Prasanna Gai

Prasanna Gai is Professor of Macroeconomics at The University of Auckland. He was appointed as Special Adviser to the Governor of the Bank of Canada (2010–2011) and as the Academic Fellow of the Reserve Bank of New Zealand (2012). Prior to his current position, Professor Gai was Professor of Economics at the Australian National University and served as Senior Adviser at the Bank of England, responsible for directing its financial stability research. Professor Gai has published widely on financial stability and international monetary issues. He holds a DPhil and MPhil in Economics from the University of Oxford and a Bachelor of Economics (Honours) from the Australian National University.

Andrew G Haldane

Andrew Haldane is Executive Director, Financial Stability at the Bank of England. In this role, he has responsibility for developing Bank policy on financial stability issues and the management of the Financial Stability Area. Andrew is a member of the Bank's Financial Stability Executive Board and the new Financial Policy Committee. He is a member of various international public policy committees, economics associations, editorial boards and academic advisory committees. Andrew has written extensively on domestic and international monetary and is co-founder of 'Pro Bono Economics', which aims to broker economists into projects in the charitable sector. He holds an MA in Economics from the University of Warwick and a BA in Economics from the University of Sheffield.

Alexandra Heath

Alexandra Heath is Head of Economic Research Department at the Reserve Bank of Australia. Prior to this, she was Deputy Head of Domestic Markets Department and Deputy Head of International Markets and Relations. She has also held positions in a number of areas in Economic Group and was seconded to the Bank for International Settlements in Basel, Switzerland. She has worked on a variety of topic areas including the impact of financial regulation on financial markets, global imbalances, the foreign exchange market, macroeconomic forecasting and labour market dynamics. Dr Heath holds a PhD and MSc in Economics from the London School of Economics and a BEc (Hons) from the University of Sydney.

Grahame Johnson

Grahame Johnson is the Deputy Chief of the Financial Markets Department (FMD) at the Bank of Canada. He is responsible for a range of financial market-related activities, including the oversight of the domestic and foreign trading activities of the Bank and the market intelligence function. Since joining the Bank of Canada in 2001, he has held a number of senior roles in FMD, and has extensive knowledge of markets, the financial system, and monetary and funds management policies. Prior to joining the Bank, he worked at CIBC for 10 years, where he traded a range of financial products, including government bonds, interest rate swaps and options. He is a graduate of Queen's University, Kingston, Ontario, and is a Chartered Financial Analyst.

Sujit Kapadia

Sujit Kapadia is a senior manager in the Prudential Policy Division at the Bank of England. His team is responsible for advising the Bank's Financial Policy Committee on the design and implementation of cyclical macroprudential policies and leads on the Bank's contributions to the international debate on reforming banking regulation in Basel and Europe. In previous roles, he made a leading contribution to the development of the Bank's stress-testing model, RAMSI; led on the Bank's input into the calibration of the Basel III capital requirements; and was a founder member of the Financial Policy Committee Secretariat. He also had a spell at the Reserve Bank of India in 2013, reviewing aspects of their monetary policy framework and assessing their financial literacy initiatives. Dr Kapadia's research encompasses macroprudential policy, banking regulation, stress testing, financial networks and contagion. He holds a PhD in Economics from the University of Oxford.

Todd Keister

Todd Keister is Professor of Economics at Rutgers University. He has previously been an Assistant Vice President at the Federal Reserve Bank of New York and a Professor of Economics at the Instituto Tecnológico Autónomo de México in Mexico City. He has also held visiting positions at the University of Texas in Austin, the European University Institute and New York University. Much of his research has focused on developing models of financial fragility and macroeconomic volatility that can be used to assess the role of self-fulfilling beliefs and to evaluate both government and central bank policies. He currently serves on the editorial boards of *Macroeconomic Dynamics* and the *Journal of Mathematical Economics*. Professor Keister holds a PhD in Economics from Cornell University and a BS in Computer Science and Economics from Duke University.

Gerard Kelly

Gerard Kelly is an Economist in the Economic Research Department of the Reserve Bank of Australia. His research has focused on topics including financial market infrastructure, international trade and structural change in the Australian economy. He holds a Bachelor of Science (Hons), a Bachelor of Arts and a Master of International Economics and Finance from the University of Queensland.

Matthew Lilley

Matthew Lilley is a graduate economist in the Economic Research Department at the Reserve Bank of Australia. He holds a Bachelor of Economics (Hons) from the University of Sydney.

Mark Manning

Mark Manning is Deputy Head of Payments Policy Department at the Reserve Bank of Australia, with responsibility for the Reserve Bank's oversight of payments, clearing and settlement systems and associated policy and research. He joined the Reserve Bank in 2008 on secondment from the Bank of England, returning in a permanent role at the start of 2012. Previously he held a number of positions at the Bank of England in the Financial Stability Directorate, including in financial market infrastructure policy and research, prudential policy and market surveillance. Before entering central banking in 2002, Mark spent several years as a fund manager in the City of London, including spells at Goldman Sachs Asset Management and Kleinwort Benson Investment Management. Mark has published a number of articles and research papers on payments and financial market infrastructure issues, and is co-editor of a book entitled *The Economics of Large-value Payments and Settlement: Theory and Policy Issues for Central Banks*. He holds an MSc in Economics from University College London, an MSc in Finance from the London Business School and a BSc (Econ) Hons from the University of London.

Silvia Miranda Agrippino

Silvia Miranda Agrippino is an Economist at Now-Casting Economics. Prior to this she was a Post-Doctoral Researcher at the Department of Economics at London Business School and a Teaching Fellow of Quantitative Methods at the School of Economics Finance and Management at the University of Bristol. Her research interests include applied macroeconometrics, factor models and forecasting. Dr Miranda Agrippino holds a PhD in Economics from Bocconi University, Milan, a Master in Economics from Universitat Pompeu Fabra, Barcelona, and a Bachelor (*summa cum laude*) from Bocconi University.

Cyril Monnet

Cyril Monnet is Professor of Economics at the University of Bern and Program Manager Doctoral Courses at the Study Center Gerzensee. Previously he held the positions of Senior Economist in the

Research Department of the European Central Bank and Senior Economic Advisor in the Research Department of the Federal Reserve Bank of Philadelphia. His research focuses on monetary economics, financial intermediation and the design of financial markets. His research is regularly published in the main international economic and finance journals. Professor Monnet received his PhD in Economics from the University of Minnesota where his adviser was Narayana Kocherlakota.

Benjamin Nelson

Benjamin Nelson is Senior Economist in the Monetary Strategy Team, Monetary Assessment and Strategy Division, at the Bank of England, and a member of the Centre for Macroeconomics, London. He joined the Bank of England in 2009 and has written on international trade and on macroeconomics, with a focus on financial instability and macroprudential policy. He holds a DPhil in Economics from Nuffield College, Oxford, and BA and MPhil degrees from Oxford.

Kevin Nixon

Kevin Nixon is Deputy Managing Director at the Institute of International Finance (IIF), where he has responsibility for both regulatory affairs and membership relations. Prior to the IIF, he was Executive Director, Head of Regulatory Reform, for the Westpac Group. In this role, his focus was the international regulatory reform agenda, engaging in the debate globally with regulators, associations and other stakeholders, assessing the implications and ensuring the Westpac Group was positioned to respond. With a career in banking spanning more than 25 years, he has held a range of positions at several major international banking groups, and was Director-Markets at the Australian Financial Markets Association from 2008 to 2010. He has also lectured on international finance, investment and risk at Macquarie University. He holds a BSc in Applied Mathematics (Hons) from the University of New South Wales.

Richard Portes CBE

Richard Portes is Professor of Economics at the London Business School, a position he has held since 1995, and President of the Centre for Economic Policy Research (which he founded in 1983). He was Directeur d'Etudes at the Ecole des Hautes Etudes en Sciences Sociales in Paris from 1978 to 2011, a Rhodes Scholar and a Fellow of Balliol College, Oxford, and has also taught at Princeton, Harvard (as a Guggenheim Fellow), and Birkbeck College (University of London). In 1999 and 2000, he was Distinguished Global Visiting Professor at Haas Business School, University of California, Berkeley, and in 2003 and 2004 he was Joel Stern Visiting Professor of International Finance at Columbia Business School. He is also an elected Fellow of the British Academy and of the Econometric Society. He was decorated Commander of the British Empire (CBE) in the Queen's Honours List in 2003. He is Co-Chairman of Economic Policy and a member of the Bellagio Group on the International Economy. He has written recently on global imbalances, the CDS markets, international liquidity, currency wars, and the euro area crisis. Professor Portes holds a DPhil from Oxford University.

Hélène Rey

Hélène Rey is Professor of Economics at the London Business School. Until 2007, she was at Princeton University as Professor of Economics and International Affairs in the Economics Department and the Woodrow Wilson School. Her research focuses on the determinants and consequences of external trade and financial imbalances, the theory of financial crises and the organisation of the international monetary system. She demonstrated in particular that countries' gross external asset positions help predict current account adjustments and the exchange rate.

In 2005 she was awarded an Alfred P. Sloan Research Fellowship. She received the 2006 Bernácer Prize (best European economist working in macroeconomics and finance under the age of 40). In 2012 she received the inaugural Birgit Grodal Award of the European Economic Association honouring a European-based female economist who has made a significant contribution to the Economics profession.

In 2013 she received the Yrjö Jahnsson Award (European economist under 45 years old who has made a contribution in theoretical and applied research that is significant to economics in Europe), shared with Thomas Piketty. Professor Rey is a Fellow of the British Academy. She is on the board of the *Review of Economic Studies* and associate editor of the *American Economic Journal: Macroeconomics*. She has been elected member-at-large of the Council of the European Economic Association. She is a Research Fellow at the Centre for Economic Policy Research and Research Associate at the National Bureau of Economic Research.

She is on the Board of the Autorité de Contrôle Prudentiel, a member of the Commission Économique de la Nation and of the Bellagio Group on the International Economy. She was a member of the Conseil d'Analyse Économique until 2012. She writes a regular column for the French newspaper *Les Echos*. Professor Rey received her undergraduate degree from École Nationale de la Statistique et de l'Administration Economique, a Master in Engineering Economic Systems from Stanford University and her PhDs from the London School of Economics and the École des Hautes Études en Sciences Sociales.

Eric Santor

Eric Santor is Deputy Chief, International Economic Analysis Department (INT), at the Bank of Canada. After joining the Bank in 2001 as an Economist in the Monetary and Financial Analysis Department, he then assumed increasing responsibilities through his roles as a Principal Researcher, Assistant Chief, Research Adviser and, most recently, Research Director in INT. He investigates issues relating to the international monetary system and global financial architecture, the role and governance of the International Monetary Fund, and the incidence and effects of unconventional monetary policy. He holds a PhD in Economics from the University of Toronto and a BA (Hons) from the University of Western Ontario.

Bernd Schwaab

Bernd Schwaab is a Research Economist at the European Central Bank's Financial Research Division, where his focus is on financial econometrics, asset pricing and risk management. His joint research has been published in journals such as the *Journal of Econometrics*, the *Journal of Business* *and Economic Statistics*, and the *Review of Economics and Statistics*. Previously he has worked for Deutsche Bank and HSBC, and from October to November 2009 he was a visiting PhD student at the University of Chicago (Booth). He holds a PhD in Economics from Tinbergen Institute and Vrije Universiteit Amsterdam, an MPhil in Economics from Tinbergen Institute and an MA in Economics from Clark University, Massachusetts.

Manmohan Singh

Manmohan Singh is a Senior Economist at the International Monetary Fund (IMF) in Washington DC. Previously he was with ABN Amro Bank's emerging market syndicate team (Amsterdam/London). He has written extensively on topical issues including shadow banking, deleveraging in financial markets, rehypothecation and velocity of collateral, and counterparty risk in OTC derivatives. He was the first to identify the role of cheapest-to-deliver bonds as a proxy for recovery value in CDS instruments. Dr Singh has led workshops for the IMF to official sector policymakers on strategic asset allocation and regulatory issues. His articles have regularly appeared in the *Financial Times*, *Wall Street Journal*, *Euromoney*, *The Banker*, *Risk*, *The Economist* and the *Journal of Investment Management*. His work experience covers several countries including the United Kingdom, the United States, Chile, India and Japan, and more recently peripheral Europe. Dr Singh holds a PhD in Economics and an MBA from the University of Illinois (Urbana–Champaign). He received his BS in Economics and Mathematics (*magna cum laude*) from Allegheny College, Pennsylvania.

Jason Wu

Jason Wu is Chief of the Monetary Policy and Dealer Analysis Section at the Federal Reserve Board. The Section studies the interaction between monetary policy, dealer-intermediated markets and financial institutions outside of the trading banking system. Previously, he was an Economist in the Division of Banking Supervision and Regulation at the Federal Reserve Board, and worked extensively on the formation and implementation of Basel capital regulations for banks' trading books. His current research interests are financial intermediation, banking and econometrics. He holds a PhD and MSc in Economics from the University of Wisconsin-Madison and a Bachelor of Commerce with first class honours from the University of Auckland.

Arthur Yuen

Arthur Yuen is Deputy Chief Executive of the Hong Kong Monetary Authority (HKMA) in charge of banking policy, development and supervisory issues. He joined the HKMA in 1996 as Head of Administration, taking up various responsibilities including research and liaison on China economic and market development issues before being appointed Head of Banking Supervision in 2000. He took up the position of Executive Director (Banking Development) in July 2004, Executive Director (Banking Supervision) in June 2005 and Executive Director (External) in July 2008. He was appointed to his present position on 1 January 2010. Before joining the HKMA, Mr Yuen worked in the Hong Kong Securities and Futures Commission for two years after having served as an Administrative Officer in the Hong Kong Government for over eight years.

List of Conference Participants

Franklin Allen	Wharton School of the University of Pennsylvania
Chris Aylmer	Reserve Bank of Australia
Morten Bech	Bank for International Settlements
Matthew Boge	Reserve Bank of Australia
Jean-Pierre Danthine	Swiss National Bank
Kevin Davis	Australian Centre for Financial Studies
Guy Debelle	Reserve Bank of Australia
Piti Disyatat	Bank of Thailand
Malcolm Edey	Reserve Bank of Australia
Yihan Fang	Monetary Authority of Singapore
Ippei Fujiwara	Australian National University
Prasanna Gai	The University of Auckland
Joel Grant	Australian Prudential Regulation Authority
Steve Grenville	Lowy Institute
Nicolas Groshenny	The University of Adelaide
Neil Grummitt	Australian Prudential Regulation Authority
Alexandra Heath	Reserve Bank of Australia
Stella Huangfu	The University of Sydney
Jiang Huifen	People's Bank of China
Grahame Johnson	Bank of Canada
Jonathan Kearns	Reserve Bank of Australia
Todd Keister	Rutgers University
Gerard Kelly	Reserve Bank of Australia
Christopher Kent	Reserve Bank of Australia
Mariano Kulish	University of New South Wales
Matthew Lilley	Reserve Bank of Australia
Philip Lowe	Reserve Bank of Australia
Mark Manning	Reserve Bank of Australia
Kevin Nixon	Institute of International Finance
Nick Palmer	Australian Prudential Regulation Authority
Richard Portes	London Business School
Bruce Preston	Monash University
Meghan Quinn	The Australian Treasury
Hélène Rey	London Business School

Bernd Schwaab	European Central Bank
Toshitaka Sekine	Bank of Japan
Manmohan Singh	International Monetary Fund
Grant Spencer	Reserve Bank of New Zealand
Chris Stewart	Reserve Bank of Australia
Paul Veerhuis	Australian Prudential Regulation Authority
Jason Wu	Board of Governors of the Federal Reserve System
Arthur Yuen	Hong Kong Monetary Authority
Qin Zhang	People's Bank of China Representative Office for the South Pacific

Acknowledgement

The editors are grateful to Wendy Baker, Paula Drew, Phillipa Kelly, Kelly O'Brien, Lydia Papandrea, Rachel Williams and the staff of Economic Research and Information Departments for much help in organising the Conference and producing this volume.

Other Volumes in this Series

2012	Property Markets and Financial Stability
2011	The Australian Economy in the 2000s
2010	Reserve Bank of Australia 50th Anniversary Symposium
2009	Inflation in an Era of Relative Price Shocks
2008	Lessons from the Financial Turmoil of 2007 and 2008
2007	The Structure and Resilience of the Financial System
2006	Demography and Financial Markets
2005	The Changing Nature of the Business Cycle
2004	The Future of Inflation Targeting
2003	Asset Prices and Monetary Policy
2002	Globalisation, Living Standards and Inequality
2001	Future Directions for Monetary Policies in East Asia
2000	The Australian Economy in the 1990s
1999	Capital Flows and the International Financial System
1998	Unemployment and the Australian Labour Market
1997	Monetary Policy and Inflation Targeting
1996	The Future of the Financial System
1995	Productivity and Growth
1994	International Integration of the Australian Economy
1993	The Exchange Rate, International Trade and the Balance of Payments
1992	Inflation, Disinflation and Monetary Policy
1991	The Deregulation of Financial Intermediaries
1990	The Australian Macro-Economy in the 1980s
1989	Studies in Money and Credit